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PROBABILITY ESTIMATES OF THE CAPACITIES OF INTERMEDIATE PUPILS TO UNDERSTAND SELECTED PHYSICAL SCIENCE GENERALIZATIONS. FINAL REPORT.

BY- SMITH, GARY R.
WAYNE STATE UNIV., DETROIT, MICH.

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THE CAPACITY OF INTERMEDIATE PUPILS TO UNDERSTAND AND RETAIN GENERALIZATIONS RELATED TO SIMPLE MACHINES, ELECTRICAL ENERGY, AND HEAT ENERGY WAS INVESTIGATED. A STRATIFIED RANDOM SAMPLE OF APPROXIMATELY 1,200 FOURTH, FIFTH, AND SIXTH GRADE PUPILS WAS SELECTED FROM THE METROPOLITAN DETROIT AREA. GENERALIZATIONS FOR THE THREE PHYSICAL SCIENCE AREAS WERE SELECTED AND VALIDATED. TEACHING UNITS WERE DEVELOPED, AND A MULTIPLE-CHOICE TEST WAS CONSTRUCTED FOR EACH UNIT. THE UNIT TESTS WERE GIVEN BEFORE INSTRUCTION, IMMEDIATELY AFTER INSTRUCTION, AND THREE TO FIVE MONTHS AFTER INSTRUCTION HAD BEEN COMPLETED. STANDARDIZED TESTS OF READING COMPREHENSION, SCIENCE ACHIEVEMENT, AND VERBAL INTELLIGENCE WERE ALSO USED. A COMPUTER PROGRAM WAS DEVELOPED TO PROVIDE A DIAGNOSTIC FILE FOR EACH INDIVIDUAL STUDENT. THE RESULTS FOR THE STUDY PROVIDE PROBABILITY ESTIMATES OF THE INTERMEDIATE PUPILS' SUCCESS IN UNDERSTANDING MAJOR IDEAS ABOUT SIMPLE MACHINES, ELECTRICAL ENERGY, AND HEAT ENERGY. RESULTS OF THE STUDY INDICATE (1) THERE WAS NO SIGNIFICANT DIFFERENCE IN PUPIL ACHIEVEMENT WHEN COMPARING INSTRUCTION BY SCIENCE SPECIALISTS AND NON-SPECIALISTS, AND (2) PUPILS IN LOW SOCIOECONOMIC GROUPS SCORED SIGNIFICANTLY LOWER THAN PUPILS IN HIGH SOCIOECONOMIC GROUPS. UNIT PLANS, EVALUATION MATERIALS, AND AN EXTENSIVE BIBLIOGRAPHY ARE PROVIDED. (DS)

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U.S. DEPARTMENT OF
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Contract No. OE-5-10-101

Gary R. Smith

August 1967

The research reported herein was performed pursuant to a contract with the Office of Education, U. S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

Wayne State University

Detroit, Michigan

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Finally, the researcher would like to express his appreciation to his colleagues in the College of Education and to the large number of students who participated in this project at various times throughout the three years. They have consistently given abundantly of their time, energy, and interest in the project. Although space does not permit a listing of their names, I wish to acknowledge that their interest and support has been a bulwark throughout the project.

# I. INTRODUCTION

A. Problem. Typically, the elementary school program includes instruction in several subject areas, e.g., reading and language arts, arithmetic, science, social studies, art, music. Blackwood's study ( 6 ) has indicated that science instruction in elementary schools: 1) commands 10% or less of the pupils' time in school, 2) is presented by a classroom teacher with little or no help from a science consultant, 3) depends heavily upon one or more textbooks for science content, and 4) is taught to groups of 35 or more pupils by a teacher who is responsible for teaching several subjects, although in large shcool districts some groups may be taught by a special science teacher. During the past three decades, little empirical evidence has been collected to identify the specific science concepts or generalizations which elementary school children would be able to understand if given competent and efficient instruction under the restrictions of limited time, available personnel, and material resources which typify elementary school science programs throughout the nation.

Without this information, it has been very difficult for elementary school curriculum groups to organize an adequate program in science. Many school districts have simply adopted a science textbook series for all grades. The publisher's scope and sequence chart has become a fundamental element in the science programs of those districts. In some cases, the plan of instruction provided in the scope and sequence chart may be modified by the school and teacher to provide for a study of local science phonomena. For those districts, the official curriculum guide is a blend of all of the ideas in the publisher's scope and sequence chart with provisions for study of local science phenomena.

Unfortunately, it has been a practice of some publishers of elementary school science textbooks to build their scope and sequence charts by selecting those topics which are common to the curriculum guides of school districts throughout the nation. In this way the publishing company has planned to have a textbook which it could sell to school districts throughout the nation.

This circularity provides an inadequate foundation for an excellent science program for elementary school pupils. It seems obvious to the writer that something should be done to break this cycle, and provide reliable information for adequate curriculum decisions. There is a continuing need for several normative studies to determine which concepts in the physical and biological sciences can be understood by elementary school pupils. This evidence should be founded upon what elementary school children could learn as a result of competent and efficient instruction under existing circumstances, e.g., using available teachers, texts, apparatus. The collection of evidence should follow accepted sampling procedures in order that the results of the normative studies may be generalized legitimately to larger populations of elementary school pupils. This information should be reported in a form which could be readily used by curriculum planning groups throughout the nation.

It is important to note that these normative studies would merely provide one block of evidence to guide the organization of the elementary school science curriculum. The norms should not be considered absolute standards. On the contrary, they should serve as a set of "bench marks" to guide the curriculum decisions and as an aid in the appraisal of the accomplishments of proposed innovations in science instruction. The present study attempted to provide one small segment in the block of evidence which is needed.

B. Objectives. This investigation was undertaken to accomplish the following specific objectives:

1) Identify several valid and significant generalizations about electricity, heat energy, and simple machines which form the content of three units of instruction for pupils in the intermediate grades.

2) Construct achievement test items to provide estimates of pupils' understanding of each of these generalizations.

3) Present the three units of instruction to randomly selected classes of pupils in the Metropolitan Detroit area.

4) Use item analyses of each unit achievement test to determine the per cent of pupils who understood each generalization before instruction and after instruction.

5) Arrange the per cent correct responses to serve as probability estimates that other pupils will understand a specific generalization.

6) Document the accuracy of these probability estimates by providing estimates of their probable error.

7) Publish these probability statements in a form which would be readily usable by curriculum planning groups throughout the nation.

8) Use a computer program and the empirically derived

probability estimates to make tentative curriculum recommendations for the classes in schools participating in this study.

C. Review of Significant Literature. In this section of the report, the writer has identified some of the salient elements which appear to be directly related to this study. Perforce, this must be a superficial summary, but the report's list of references identifies sources of more information about any one of the major elements reported in this review.

At least three major components should be identified to help the reader interpret the intent, the effort, and the products of this study. These three main segments are: 1) the contributions of other science educators and government agencies to science education during the past decades, 2) the use of language in the classroom, and 3) the meaning and interpretation of the term "probability". In the following remarks, the researcher has attempted to explain his impressions of these major segments and the extent to which they have influenced his efforts in this project. They have been discussed in the order mentioned above.

### 1. Contributions of Science Educators and Government Programs

It seems that the major impetus for directing and formulating objectives for science instruction in the elementary schools has been provided by at least three agents. Specifically, they may be identified as: a) science educators and their publications, b) agencies and legislation of the federal government, c) the theoretical and experimental work of certain prominent psychologists and other academicians. Frequently, the efforts of these agents have overlapped. Sometimes they have been coordinated, and often they have appeared to work in opposition to one another.

a. Influence of Science Educators. One may distinguish at least two groups of science educators. In one group there is the basic research scientist who has ordinarily studied intensively in a science discipline as an undergraduate student and as a graduate student. The basic research scientist ordinarily teaches his specialty at a university or conducts research in his special field and he has rarely conducted prolonged study of ways to improve instruction of his science specialty in the elementary schools and the secondary schools.

In the second category, the science educationist has ordinarily studied deeply in one or more science disciplines as an undergraduate student and/or graduate student but his research and teaching have been directed primarily toward improving the science instruction in elementary schools or secondary schools. Although these are not mutually exclusive classes of the group, "science educators", the distinction is clearly made by the National Science Foundation (15 ) and others (90 ).

Herbert Smith (76 ) has summarized the historical background and major contributions of science educationists who attempted to establish and direct science instruction in the elementary and secondary schools of the United States.

It seems that Craig's work ( 18) during 1927-1934 marked the entrance of science into the elementary school program and publication of the first science textbook for elementary schools. The products of Craig's work and thought seemed to dominate the elementary school program during the following two decades. This period of 1934 through 1954 was punctuated by the studies of Haupt ( 28), Hill ( 30), Read ( 63), and other science educationists, who attempted to explicate the role of science in the elementary school. During this period, educational research in science and other curriculum areas was crude and not " academically respectable." Many of these scholars relied upon the sporadic efforts of graduate students to explore certain persistent problems:

What science content should be taught?
When shall it be taught?
What procedures yield optimum success in science education?
What practices in science education occur in the schools?
When and where can "the scientific method": or "problem solving"be taught?

To a large extent, these identical questions or very similar ones are being posed by contemporary science educators. They have not been answered by persuasive evidence. They continue to be foci of research and apprehension.

During 1952 there was an attempt by McCarthy to discover the mental age when certain concepts about machines could be taught( 45). Similar studies for heat, atomic energy, sound, and light were conducted by Starrett ( 79), Reid ( 64), Nelson ( 51), and Smith ( 72). In large measure, these research efforts have been isolated and have had a trivial impact upon the science programs of elementary schools throughout the nation. On the other hand, the leading science educationists (17,23,8,68)have relied primarily upon the science textbook to communicate their ideas about science to teachers and to children in elementary schools of the nation. As Blackwood ( 6 ) has indicated, the science textbook is the omnipresent influence in the school systems which he surveyed.

The basic research scientist emerged as the major force to influence elementary school science curricula during the decade of 1957-1967. This ascendancy occurred in large measure through the financial support of the National Science Foundation ( 37).

b. *Influence of Federal Government*. The federal government has exerted a tremendous influence upon the direction and implimentation of science instruction in the schools of the nation. When the National Science Foundation ( 50 ) was created in 1950, its institute programs began to exert a major influence on the high school science teachers early in 1954. Subsequently, the major curriculum programs in elementary and secondary school science, i.e., PSSC, BSCS, ESS, AAAS, SCIS, USIP, and Minnemath, have emerged to give additional impetus by providing curriculum materials and consultant services to many elementary schools' science programs. ( 50 ).

In the elementary schools, the major thrust of these new programs has been toward the development of instructional materials and procedures to cultivate the "discovery" or "process" goals of science ( 37 ). These projects have generally relied upon a combined effort of basic research scientists and classroom teachers to develop their units of instruction. Although these materials have been produced in considerable quantities and distributed widely throughout the nation, reports of their contributions to improve the quality of science instruction in representative elementary schools have been sparce and often casual ( 21 ).

Recently, the science educationist has been participating more actively in the federally supported programs than he has in the past. Perhaps one of the most promising artifacts of this collaboration of science educationists, research scientists, and school personnel, was the National Science Teachers Association document *Theory Into Action* ( 84 ). This document provided the axioms of the conceptual schemes and the science processes which may be expanded into curriculum materials for instruction within the nation's elementary schools. It apparently represented a concensus of research scientists, science educationists and school personnel upon the salient goals of science education (K-12). One of the major architects of this document has initiated a research project to attempt to impliment the ideas expressed in the NSTA document (16 ).

The National Defense Education Act must receive major credit for supplying the schools with apparatus and materials which would support the quality of science instruction advocated by most of the recently conceived programs in science education (88 ).

The impact of the Elementary and Secondary Education Act of 1965 ( 53) will undoubtedly be far reaching, although it is too soon to estimate which of its components will be predominant. Title III of ESEA provided funds and encouragement for innovations in all curriculum areas, including science education. One can only speculate upon the extent to which this call for improvement will be heeded.

c. Influence of Psychologists and Other Academicans. Bruner summarized the problems, hopes, and intent of the basic research scientists and other academicians following their 1958 meeting at the Woodshole Conference ( 9 ). He asserted:

> "We make the bold hypothesis that any subject can be taught to any child at any stage of his development in some effective and intellectually honest form."

This statement opened the door to the vast array of content goals and process goals which have been accumulating in the physical and biological sciences for generations. Programs flourished. In the ensuing decade, elementary school children have received instruction in mathematical logic under the direction of Suppes (81 ), in inquiry skills advocated by Suchman (80 ), in advanced principles of astronomy recommended by Atkin ( 2 ), and through a science program which emphasized processes of science developed by AAAS Commission on Science Education (43 ).

There has been a dearth of published criticism to this combined effort of prominent research scientists and psychologists who were amply supported by federal funds. Ausubel ( 3 ) remonstrated that the discovery approach to teaching science could not achieve all the goals of science education and that it was essential to provide meaningful and systemetic instruction of concepts. Herbert Smith (75 ) criticized the vested interests which were developing as a consequence of the NSF Institute Programs. Gary Smith ( 73) rejected "Bruner's Hypothesis" as a hypothesis and chided Suppes(70) for over generalizing the results of his work in teaching logic to fifth and sixth grade pupils. However, these critical remarks have not substantially influenced the direction of this exploratory work in studying children's science concepts or their understanding of the process of science.

On the other hand, the research and conclusions of Piaget (59,32), have been accumulating supporting evidence and adherents since his initial studies of children's language, circa 1929. This cumulative support has generated for Piaget's views a renaissance of interest in the United States (60 ). His evidence and arguements in support of developmental stages in the cognitive growth of children have caused several leaders in the national curriculum groups in science education to reconsider their goals and procedures (60 ). Among other things, Piaget has raised questions about the conservation of the meaning of concepts and the age level at which propositional logic emerges. If a child's intellectual impression of a physical object does not remain "invariant" from one moment to the next, as Piaget has contended is the case for children in the preoperational state, then there is a basis for questioning the merit of instructional programs which devote time and resources toward helping the pupil "discover" the abstract concept of an object.

Several replications of Piaget's work have been conducted in the United States and in Western Europe (22 ). Although there are conflicting reports of the precise age levels when a particular developmental stage occurs in any child, the replications have tended to support the ordered sequence of stages in congition specified by Piaget.

Cagen has stated that the basic point of disagreement which separates some American psychologists from accepting Piaget's model of children's cognitive development is Piaget's assumption that the logical structures of cognition are independent of language (10 ). When one considers that Piaget's supporting evidence is consistently drawn from interviews with children, the researcher shares the misgivings alluded to by Cagen.

Although some of the leaders of the national curriculum projects appear to be responding favorably to the influence of Piaget's research (60 ), there does not seem to be a grand design emerging from any single national curriculum group or combination of curriculum groups. This is a synthesis which may be achieved in the decades ahead.

Some psychologists have been exploring an information processing model of concept formation. Miller (49 ) has suggested that there is a finite number of bits of information which an individual may be able to bring into some relationship, when relying only upon the information processing capabilities of the mind, rather than the written coding of information.

In support of this, McLaughlin, (47 ) in the Northampton College of Advanced Technology in London, has proposed that a "psycho-logic" may be incorporated into Piaget's view. That is, he suggested that a child's capacity to hold certain "concepts" in his memory may limit the extent to which the child can process information and therefore imposes a limit on the level of thinking at various age levels. As the child grows older his capacity to hold a larger number of "chuncks"of information: is increased. McLaughlin's experimental work in support of this has been conducted primarily through the use of norms of digit span tests conducted by Wechsler in 1949 and 1955. He expressed the viewpoint that the complexity of concepts and/or generalizations which an individual child might assimilate would be directly related to the number of separate concepts which he might be able to process intellectually at a given period of time.

Hunt ( 31) has pursued this line of research vigorously by utilitzing data processing equipment to build matrices of verbal symbols which he describes as a "Concept Learning System." This seems to be a cybernetic model of concept learning which is related to the philosophy of Wiener ( 94) and Ashby ( 1 ). In education, there are several persons advocating this approach (77 ). At least one science educator has described a cybernetic model (52 ) to be used in science education.

Smith (71 ) reported a computer program which would make curriculum recommendations in terms of a pre-conceived decision format. He has also suggested that a "mapping" of pupils' comprehension of certain topics may be facilitated through the use of symbolic logic and computer analysis of the response patterns to multiple choice test questions (69 ). The present study represented an effort to collect reliable evidence, which might serve as input to the models described by Smith.

### 2. Use of Language in the Classroom

a. Semantics of Classroom Language. Weaver (91 ) has been very critical of textbooks and their explanations of concepts and generalizations taken from the physical sciences. He has contended that these statements in certain elementary school textbooks have been confusing and erroneous.

Ruchlis (65 ) has taken exception to Weaver's remarks and argued that it is inappropriate to say that there is simply one "scientific" meaning for a term or expression, and to ignore the large number of other meanings for the same word or statement which occurs in the daily language use of non-scientists. Ruchlis asserted that semantic difficulties of communicating with children in a language which is meaningful to them as opposed to a language which has achieved concensus among physical scientists is at the heart of the problem and the disagreement between himself and Weaver.

Iona ( 35) has entered into a similar dispute in the literature with a classroom teacher, Ulrich. Iona was very critical of the statements of science principles and generalizations in articles written by Chinnis (13 ) and by Ulrich (86 ). Iona objected to the poor wording and the erroneous statements of science principles, and he rejects oversimplification of these principles or what he considers to be erroneous statements which may lead to persistent misunderstanding.

In his reply to Iona, Ulrich (87 ) has acknowledged the need for valid criticism of generalizations and concepts as they have been stated in the past. He invited Iona to contribute his time and energy to prepare such a series of statements, and then Ulrich argued that it was intellectually honest to state science principles in a language which uses simple terms in order to establish meaningful communication with children in the teaching-learning situation.

It seems that at least two scholars concerned with language and communication would tend to support the view that language is a very imprecise means of communicating ideas. Hayakawa (29 ) takes the position that we live in a semantic jungle in which we are involved in a never-ending task of interpreting the barrage of words flung at us from teachers, salesmen, public officials, and the "...cries of the hawkers of soft drinks, soap chips, and laxatives who pursue us into our homes..." Hayakowa states that it is a false idea to anticipate that any single word can have a single meaning. This, in turn, directly implies that a single generalization or principle composed of single words cannot have a single meaning.

Cherry ( 12) concurs with the view that everyday language is a fragile vehicle for expressing one's ideas. He takes the position that there are not enough words to express the subtleties of every thought. In point of fact, Cherry believes that language is kept alive by common usage,by the "vulgar" and by a few thousand words which seem to be the limit of the vocabulary of most English-speaking people.

It is the view of the researcher that the language used by the teacher in the experimental classrooms and in the classrooms throughout the nation is a very imprecise vehicle for communicating any of the ideas considered principles or generalizations of science. In his view, mathematics and logic are two exact languages. Some have even argued that mathematics is simply a well developed branch of logic (38 ), but that dispute does not concern us here. The main consideration is that the language used in the elementary school classrooms to teach science or any topic can only approximate the precision of mathematics and logic. The use of language in presenting the units of instruction in this research project and the language used in evaluating pupils' understanding of those concepts or generalizations was necessarily imprecise. It represented an effort to teach a set of ideas as effectively as possible through admittedly crude medium of communication. On the other hand, it is the researcher's contention that the plan of instruction, the materials, and the teacher's presentation provided science instruction whose quality was as good or better than the science instruction conducted in other randomly selected classes in Metropolitan Detroit.

The problem is compounded when one considers that the language of the classroom is often meaningless or unintelligible to pupils from low socio-economic communities. This is the view of Bernstein ( 5 ) and others. The instruction used in this research cannot escape the problem of imprecise language which must necessarily occur when any classroom teacher meets with a group of children for the purpose of helping build meaningful ideas about some topic. The scope of this dilemma is discussed in greater detail in Appendix G.

b. *Meaning of Perception, Concept, and Generalization*. Russell ( 66) has discussed various definitions and relationships among the terms "perception", "concept", and "generalization." He has indicated that "percepts" or "perceptions" are sensory impressions which are recorded via a person's senses of sight, hearing, smelling, touching, tasting. For example, a child may see an object with four legs. A few moments later, his mother says: "That's a dog." The child's sense of sight has recorded a percept of the object with four legs. His sense of of hearing has also recorded a percept. A child may or may not consider the two sensory impressions to be related. Although this is an oversimplification of the perceptual process, this gross interpretation of "perception" has been used by the researcher in the present study.

In regard to the denotations of the term "concept", the researcher subscribes to the views of Russell ( 66) and Gagne ( 24) that this term refers to an instance when a person thinks of two or more percepts as related in some way. The thought of that relationship between two or more percepts is considered by the researcher to be an instance of a "concept". For example, a child may see a furry object with four legs. He hears his mother say: "That's a dog." The child's sense of sight has recorded a percept of the object with four legs. His sense of hearing has also recorded several other percepts. The child may or may not consider these sensory impressions or percepts related.

When a person is able to think of two or more percepts as related in some way, the thought of that perceived relationship is considered to be a "concept". For example, a child may see and feel a furry object with four legs. He hears the object make a sharp barking sound. His parent says, "That's a dog." The child's senses of sight, touch, and hearing have recorded these sensory impressions and his mind has coordinated these percepts to form a thought or concept of "dog." As the child has more experiences, i.e., opportunities to form percepts, with the same dog or other dogs, his concept of "dog" is able to increase in complexity and usefulness.

A person's concepts may be very simple and have tangible referents, e.g., dog. On the other hand, they may be very complex and abstract, e.g., energy, atom, democracy, electron, molecule.

Obviously, we do not presently have means to observe directly the "thought" or "concept" in the mind of the child. Therefore, the researcher must observe and record pupils' overt behavior as well as his verbal or written responses to stimuli. From this observed evidence, the researcher attempts to infer the condition of the concepts or generalizations in the pupil's mind.

The researcher subscribes to Gagne's view ( 24 ) that a principle or generalization is a statement expressing some relationship between two or more concepts. The term "generalization" is considered to be a synonym for the term "principle".

For example, the statement, "The dog runs fast." is considered a "generalization." The statement includes the noun concept "dog", the verb concept "runs" and the adverbial concept "fast". The statement will communicate meaningful information to a person if he has established a set of related percepts for each concept in the statement. Generalizations may be very simple as in the preceding example. On the other hand, they may be very complex, e.g., for all real numbers, $a + b = b + a$. All matter is composed of atoms.

### 3. Meaning of the Term "Probability"

The historical development of probability has been described briefly by King and Read (40 ) and its various rules and applications were discussed in popular volume by Weaver (92 ). The prominent philosopher, Carnap, has devoted considerable theoretical research to explicating the meaning of this term ( 11). In substance, Carnap believes that there are two distinctly different concepts of probability. One concept, Probability (1), refers to the extent to which some hypothesis "h" is confirmed by available evidence "e". This evidence is evaluated in terms of semantic data and not in terms of empirical data. The truth value of statements or hypotheses within this category is determined by logical analysis and these statements are Probability (1) true without regard to events in the real world.

Probability (2) is considered by Carnap to refer to the relative frequency of some property or event occuring with respect to the entire set of events which might possibly occur. This is the most thoroughly developed of the two concepts. The truth value of hypotheses or statements in this category are determined by factual or empirical evidence.

Carnap has devoted a substantial portion of his scholarly life and published research to distinguishing among these two concepts and the kinds of events to which they may be legitimately be applied. Indeed, Carnap has devoted considerable effort to defining the axioms which may be utilized to build an inductive logic where Probability (1) would have primary responsibility and would function in a manner compatible with the considerable empirical work which has buttressed Probability (2).

The mathematician and philosopher, Kemeny ( 38), has agreed that there is little debate that Probability (2), as defined by Carnap, is well established in the literature of mathematics and science as "The Theory of Probability". However, when Probability (1) enters for consideration, Kemeny says that there are at least "two and one-half schools of thought" about the appropriate means of analyzing evidence to arrive at the truth value for Probability (1) statements. Some scholars believe that relative frequencies may be used, others believe that these probability statements are not amenable to exact mathematical analysis, and Carnap leads the list of another group which has attempted to create a mathematical system for Probability (1).

In a separate discussion of probability, Papoulis (54) discussed the relationship of the theoretical models of probability and the physical phenomena to which they may be applied by scientists and engineers. He distinguished four definitions of the condept "probability": 1) the relative frequency definition of probability based upon a small number of axioms, 2) the relative frequency definition based upon *a posteriori* evidence, 3) the *a priori* definition as a ratio of favorable events to total possible events, and 4) probability may be defined as a measure of belief.

Papoulis argued that the axiomatic definition was to be preferred in the instructional program of potential scientists and engineers although the *a posteriori* relative frequency concept of probability and even the classical concept of probability have played major roles in aiding engineers in applying the theoretical models of probability. For Papoulis, the concept of probability as a measure of belief is frequently used in daily activities, but he believes that "...this form of probability has no place in the development of an exact theory."

It seems reasonable to conclude that there are various points of view regarding the meaning of the term "probability". Therefore, it is appropriate to comment briefly on the use of the concept of probability in this study. In collecting data, analysing it, and reporting estimates of "probable success" in understanding some of the generalizations, the researcher has been concerned primarily with the number of correct responses of pupils to a given test item in relationship to the total number of possible correct responses which might have been made by all pupils to that particular item. This is essentially the *a posterori* relative frequency concept (Probability (2)). Moreover, the confidence belts specified in Appendix D of this report indicated clearly that the researcher believed that it was possible to estimate the level of confidence or the degree of belief in each of the proportions which have been cited. These estimates of confidence in the proportions have been established upon the work of Pearson (58) as well as that of Tate and Clelland (83).

However, when one begins to utilize these proportions and the confidence belts, it seems to the researcher that the model of inductive reasoning described by Carnap (11) takes on considerable relevance. This model for inductive reasoning is very valuable in the judgement of the researcher. For example, someone may assert: "Sixth grade pupils can understand the generalization: 'All matter is composed of atoms." It is obvious that one can find some "sixth grade pupils" who cannot understand that generalization before or after instruction. One can also find other "sixth grade pupils" who will understand the generalization before or after instruction. Therefore, the statement does not communicate unequivocal information which can be used to arrive at some decision about sixth grade pupils and their success in understanding the generalizations. In the view of the researcher, this is a *useless statement*. It is an equivocation!

The researcher takes the position that a meaningful statement would be"Reid's study indicated that the probability is four chances in ten that sixth grade pupils will understand the generalization: 'All matter is composed of atoms." A more explicit and meaningful statement could have been made by actually referring to the particular study, to the particular sample upon which the statement was based, and to the population to whom this statement was applied. This approach is *very similar*, if not identical, to Carnap's concept of"degree of confirmation."

Undoubtedly, the literature of science education has not achieved this degree of specificity. For this reason, a large body of this literature and a corresponding volume of spoken messages at professional meetings are meaningless messages for this researcher. This is an acknowledged deficiency on the part of the researcher.

## II. METHOD OF STUDY

### 1. Sampling Procedure

The population for this study included all fourth, fifth, and sixth grade pupils in the public schools of Metropolitan Detroit. For purposes of this study, Metropolitan Detroit was considered to include the city of Detroit and all school districts which touched the city limits of Detroit.

The sampling plan was a stratified, two-stage, random sample. The population was composed of two major strata--suburban school districts and the nine districts in the Detroit Public Schools. Stage #1 in the sampling plan was concerned with the selection of school districts within each stratum, and stage #2 was concerned with the selection of public schools within the districts. The sampling unit was each elementary school in Metropolitan Detroit which contained fourth, fifth, or sixth grade pupils.

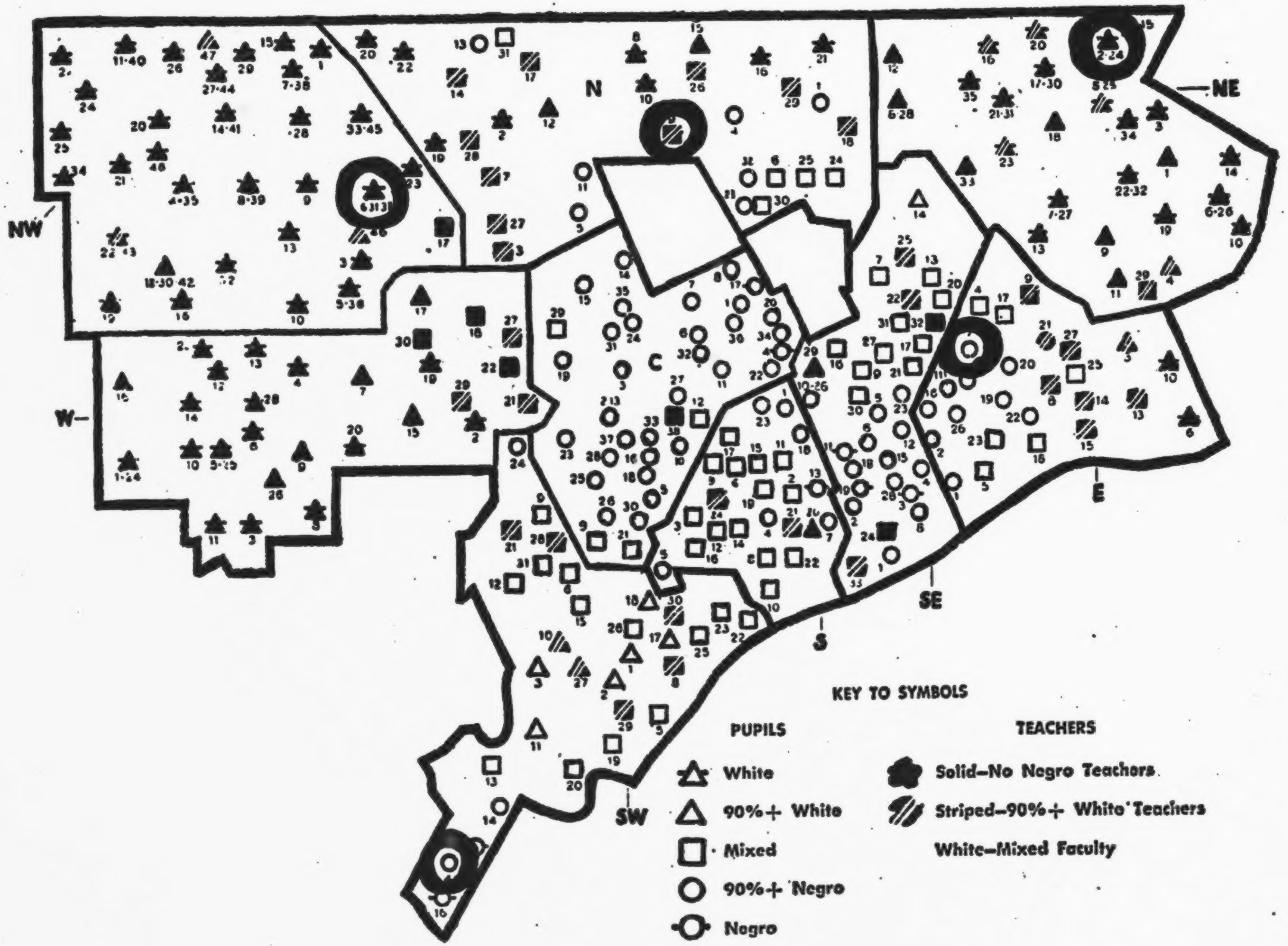
A. Selection of Sample from Detroit. A survey completed prior to this study indicated that approximately 50% of the pupils in the Detroit public schools were Caucasian and about 50% were Negro (14 ). It indicated that these pupils resided in school districts where most of the children were primarily Caucasian, primarily Negro, or there might be a mixture of the two groups in which one racial group tended to be numerically predominant. It was intended that the sample should represent this distribution. Therefore each school was classified according to one of the following catagories:

1) pupil population is 90% Caucasian
2) pupil population is 90% Negro
3) pupil population is mixed with Caucasian pupils predominant
4) pupil population is mixed with Negro pupils predominant.

Each elementary school was assigned a number and approximatly ten schools were identified by choosing numbers from a table of random numbers for each of the four categories mentioned above.

Starting with the first school selected in each of the above categories, the researcher met with the principal and science teacher in a conference to explain the purposes of the study and the obligations of the science teacher as well as the obligations of the researcher. The pupils in the classes of the science teacher were used as subjects for the study if the following conditions were met: 1) the science teacher was willing to particicipate in the study, 2) the principal and the science supervisor considered the teacher to be competent to teach science. If one of these conditions was not satisfied, the next school on the list was chosen and the principal and science teacher was contacted in a similar fashion.

Figure 1 LARGE RINGS INDICATE DETROIT SCHOOLS PARTICIPATING IN STUDY (Source: "Racial Distribution of Teachers and Pupils in Detroit Public Schools," The Detroit News, March 11, 1962, p. 12)


NW
N
NE
W
C
E
SE
S
SW
KEY TO SYMBOLS
PUPILS
White
90%+ White
Mixed
90%+ Negro
Negro
TEACHERS
Solid–No Negro Teachers
Striped–90%+ White Teachers
White–Mixed Faculty

The same random sampling procedure was followed in selecting schools and cooperating teachers in Detroit for each of the four categories of racially distributed pupil populations. It is important to note that after the purposes, procedures, and responsibilities were explained to the teacher, each teacher was free to accept or reject participation in the study. As a matter of fact all the teachers in the Detroit schools agreed to participate in the study after it was explained to them. In one situation, the teacher agreed to participate in the study but was transferred to another school in September, 1965. Therefore, there was not a representative school from category four, i.e., schools having mixed pupil population with Negro pupils predominant.

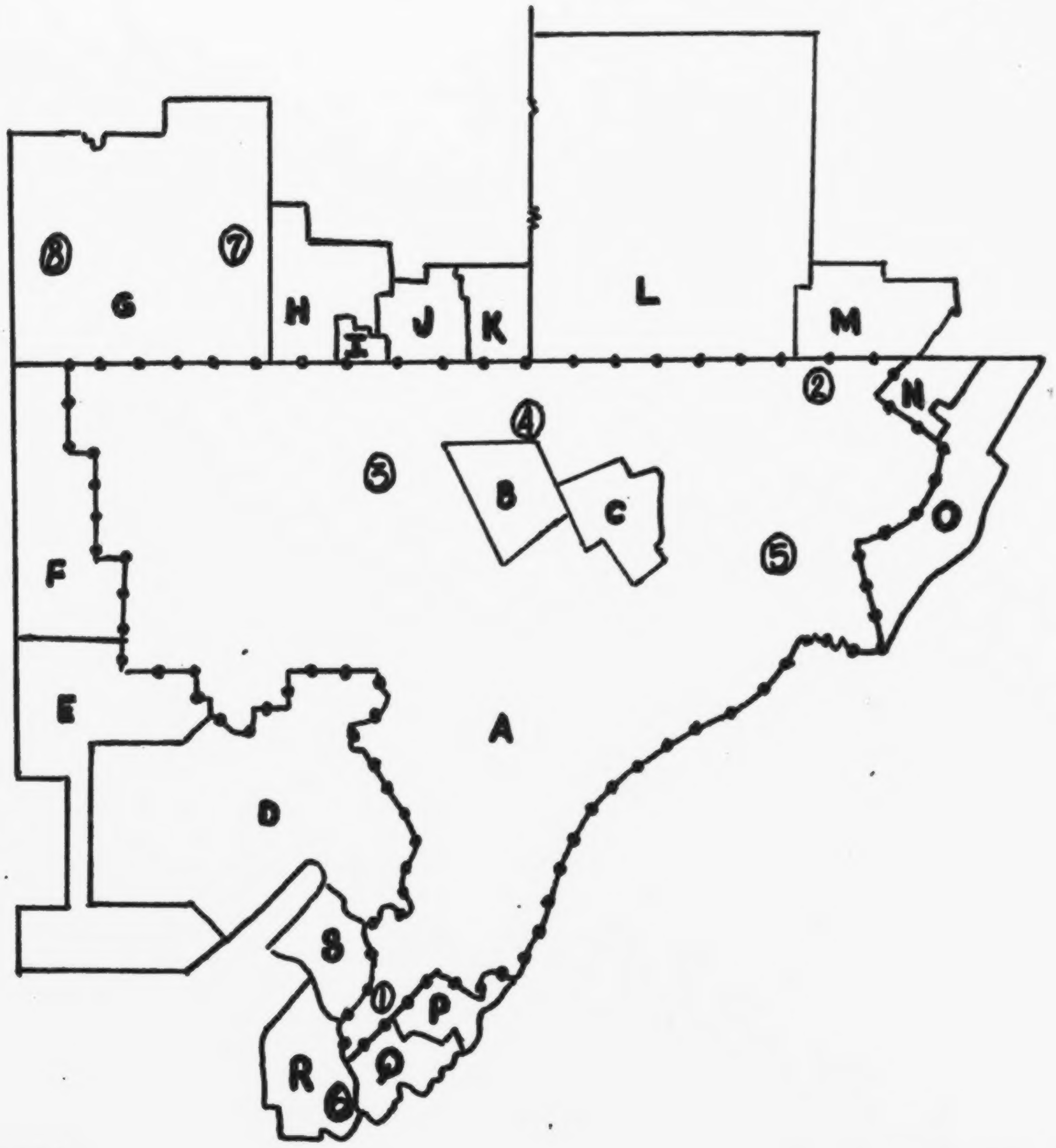
Figure 1 illustrates racial composition of the Detroit Public Schools in February, 1961, and large rings indicate the Detroit Schools which participated in the study. Since there were nine districts in the Detroit public schools, the sampling fraction with respect to districts was 5/9. The sampling fraction for schools having 90% Caucasion students was 2/94. The sampling fraction for Detroit schools having 90% Negro students was 2/66. The sampling fraction for Detroit schools having mixed Caucasian and Negro student population was 1/35.

B. Selection of Sample from Suburbs. As Metropolitan Detroit was defined in this study, there were 18 suburban school districts. The relative sizes and locations of these suburban school districts are shown in Figure 2. The writer was not able to collect information regarding racial distribution in these districts. However, it was presumed that the pupils were primarily Caucasian.

The number of pupils in each district varied from 2240 pupils in one district to 21,710 pupils in another district ( 48 ). The sampling plan was structured to permit those districts with large school populations to have an increased probability of selection over schools with a small pupil population. Each of the school districts was assigned a two-digit number from 1 to 18. Every school district with 5000 or more pupils received one extra two-digit number which was equal to or less than 36. For 10,000 pupils, two extra two-digit numbers were assigned. For 15,000 pupils, three extra two-digit numbers were assigned. For 20,000 pupils, four extra two-digit numbers were assigned. Since Dearborn was the largest suburban school district in the population, it had a total of five chances in 36 to be selected. Harper Woods with 2240 pupils had one chance in 36 to be selected.

A table of random numbers was used to select one school district. The Lincoln Park School District was selected and the Southfield Public School District was selected. These two districts represented the suburban school districts in Metropolitan Detroit.

Figure 2 LOCATIONS OF PUBLIC SCHOOL DISTRICTS IN METROPOLITAN DETROIT



Legend:
A. Detroit
B. Highland Park
C. Hamtramck
D. Dearborn
E. Dearborn Heights
F. Redford
G. Southfield
H. Oak Park
I. Royal Oak
J. Ferndale
K. Hazel Park
L. Warren
M. East Detroit
N. Harper Woods
O. Grosse Pointe
P. River Rouge
Q. Ecorse
R. Lincoln Park
S. Melvindale

*Schools participating in study are indicated by numerals

Following the pattern used to select the Detroit sample, a similar procedure was followed in explaining the project to the superintendent, curriculum coordinator, principals and teachers in each suburban district. If the district administrator, principal, and teachers were interested in participating in the project, then two schools were selected from the district by a table of random numbers. Fourth, fifth, and sixth grade pupils in those schools were used in the study if the following conditions were met: 1) the teachers were willing to participate in the study, 2) the principal considered the teachers to be competent to teach science. If one of these conditions was not met, another school was to be selected at random. Two schools were selected in Lincoln Park to participate in the study, but personnel changes were made in September, 1965, which made it impossible for teachers in one of the Lincoln Park schools to participate in the study. Two of the Southfield public schools participated in the study.

Figure 2 indicates the suburban schools which participated in the study. The sampling fraction for the suburban school districts was 2/18. In the two school districts there were 28 schools. Therefore the sampling fraction of schools within the two districts was 3/28. The sampling fraction for schools in the suburban portion of Metropolitan Detroit was 3/172.

C. Removal of Subjects from Study. The sampling plan provided that pupils might be removed from the sample for reasonable cause. If a pupil missed more than three class periods of instruction, then his test scores for that unit of instruction were not included in the analysis of the data collected for the study. It was felt that the pupil may not have had a fair opportunity to study and understand the content of instruction. A biased measurement for those pupils would merely introduce additional error variance into the analysis of the data.

If a pupil was known by the teacher to have handicaps of hearing, sight, or serious emotional problems which would handicap the child in participating in the units of instruction, then that pupil's test scores were not included in the analysis of the data. In no case was a child removed from a classroom. It was the researcher's practice to score the handicapped pupil's answer sheet like any other child's answer sheet and return the scores to the teacher. However, the pupil's scores were not included in the analysis of the test data.

## 2. Units of Instruction

A. Selection of Generalizations. A sequence of generalizations for electricity, heat energy, and simple machines was identified. An examination of the literature of science education was made in order to select generalizations which ranged from those considered to be appropriate for pupils in elementary school to those generalizations considered appropriate for students attending junior high school. Several textbooks served as the primary source for these statements (4,7,23,36,55,56,57). The fact that a statement was included in one of these major science textbooks provided an initial piece of evidence to support the validity and significance of the statement for inclusion in the unit of instruction.

Next, the researcher examined two college physics textbooks (25,93), to determine if each statement was explicitly stated or clearly implied in the college textbook. Presence of the statement in either college textbook was considered to constitute another piece of evidence to support the validity and significance of the statement.

The statements of these generalizations were presented to a university physicist, a science supervisor, and a science teacher. The consultants were asked to accept or reject these statements as valid and significant statements of ideas in physics. The statement of instructions to these consultants is presented in Appendix F. After the consultants had reviewed the statements, the researcher met with each one in a personal conference to clarify his understanding of the consultants' remarks. The researcher must accept full responsibility for any inaccuracies which might appear in any statement of generalizations or other parts of this study.

In order for a generalization to be included in the instructional plan, it had to satisfy all three of the following conditions:

1) Generalization was explicitly stated in one or more textbooks intended for pupils in elementary school or junior high school.

2) Generalization was explicitly stated or directly implied in the college physics book by White (93 ) or the college physics book by Gamow and Cleveland (25 ).

3) Generalization was judged to be valid and significant generalization by at least two of the following consultants: university physicist, science supervisor, science teacher.

B. Plan of Instruction. A unit of instruction was organized for each of the topics included in this study, e.g., simple machines, electrical energy, heat energy. It required approximately 18 to 20 class periods of instruction. A copy of each unit of instruction is shown in Appendix I of this report. The units provided that three to five generalizations would be taught during each instructional period of approximatly 45 minutes duration. The unit plan provided for introduction of new words, a textbook to be read silently and aloud in class, questions to guide class discussions, drawings for the chalkboard, and activities or demonstrations to illustrate the major ideas. A kit of apparatus was included for each experimental teacher and the kit provided the necessary materials to carry out each of the activities included in the unit plan. The kit also included three filmstrips to be used for each unit of instruction (See Appendix I).

During the 1964-1965 school year, the researcher taught a pilot class of fifth grade pupils in order to check the value of the activities, apparatus, time limits, test questions, and other aspects of the units of instruction. The insights gained from this pilot class were used to modify the units of instruction used by teachers in the experimental classes.

All teachers in the study met with the investigator in a personal conference for at least one hour or in workshops for two to three hours to discuss the ideas and activities included in each unit. All teachers agreed to use the unit plan as a guide to help them organize and direct their instruction.

The following excerpt from the "Suggestions for Teaching Unit" was included at the front of each unit plan. It provides an indication of the spirit or the intent of the unit of instruction:

1) Begin each day with a question, illustration, or activity which will capture the interests of the pupils. Whenever possible, utilize questions or objects brought to class by your pupils.

2) Elicit possible explanations or answers from several pupils. Don't tell answers immediatly. Ask a child to explain, illustrate or give reasons for accepting or offering a particular answer.

3) Guided by your judgement and the teaching circumstances give as many pupils as possible an opportunity to do the activities.

4) Use the science textbooks to expand their understanding of the ideas introduced in class. The appropriate text material is to be read silently and then aloud.

5) The concepts presented in column one of the unit plan are intended for the teacher's guidance. They are not to be copied by the children as something to memorize. It is hoped that the pupils will begin to make similar generalizations as a result of the activities, the discussions, and their reading. Encourage your pupils to generalize; but also urge them to use the vocabulary and expressions which are meaningful.

6) If circumstances permit, place apparatus in a science corner where children may repeat the activities during their free time.

7) The chalkboard illustrations may be sketched on large newsprint paper or at the chalkboard.

8) Don't try to make your pupils "heat energy experts." Help them to conclude their study with the feeling that they've learned a great deal about heat energy. They've learned the explanations for many things which they've previously taken for granted. However, there are still many things which they don't know about heat

energy. Help them to close the unit with an interest in continuing the study of heat energy.

It is important to note that each teacher was free to carry out the instruction according to his customary method of "teaching style", and to use whatever materials he had available. In previous studies conducted by the researcher, some teachers preferred to teach the units by following a problem solving method and involving all children in the experimentation. Other teachers have preferred to have one or two children demonstrate and lead class discussion. Other teachers have chosen to do the demonstrations themselves and to assume the major role of quesioning pupils. In the previous studies there have been as many different methods of instruction as there were teachers participating in the study. This was encouraged. The unit plan provided the framework of common experiences for all pupils. The kits of apparatus, filmstrips, texts, and other materials were intended to provide a minimal supply of instructional materials for all teachers.

### 3. "Self-Contained" Classroom Teachers and Special Science Teachers

One form of class instruction included in Detroit schools was the use of a special science teacher for pupils in the intermediate grades. This teacher would meet with a class of pupils for a class period of 35 to 50 minutes duration. The number of class meetings varied from two to four class periods each week. Such a science teacher would ordinarily meet five to eight classes each day. In other words, the special science teacher would have responsibility for science instruction for 250 to 300 children during a given week.

In the suburbs of Detroit, science instruction was conducted in some classes by a "self-contained" classroom teacher. This person would teach several subjects to elementary school pupils and science was one of those subjects. This classroom teacher could carry out instruction for 30 to 50 minutes each day or vary the time and duration of presentation without serious interference with the schedule of other classes in the school .

In one group of sixth grade classes, the pupils were taught by means of a "team teaching" arrangement. Under these circumstances one teacher would assume major responsibility for instruction and the two other sixth grade teachers would cooperate as it was appropriate. This arrangement permitted large group "lectures", which would be followed by small groups of pupils working in a form of laboratory activity. The instructional period for the large group lecture-laboratory activities would last as long as two hours. In their individual classrooms, the teachers would develop the reading and/or discussion of questions raised in the large group.

In one pair of sixth grade classes, a single teacher carried out instruction for both classes. This kind of cooperative arrangement between two classroom teachers is frequently found in elementary schools.

### 4. Collection of Test Results

A. Construction of Unit Achievement Tests. A multiple-choice test was constructed to measure pupils' understanding of the ideas in each unit before instruction, directly after the unit had been concluded, and three to five months after instruction had ended. One or more test items was written for most of the major generalizations included in the unit of instruction. Appendix A, B, and C show listings of the major ideas presented in each unit and the corresponding item on the unit achievement test. A copy of each unit test is included in Appendix J of this report.

It should be noted that each test item provided a modest indication of a pupil's understanding of the generalization for which the test item had been written. The multiple-choice test item attempted to determine whether or not a pupil had achieved a minimal understanding of the corresponding generalization. In a sense, the multiple-choice test question seeks to measure the pupil's understanding of the relationship between the question or stem of the test item and the "conventional" or "stereotype" answer.

Although some researchers may have a low opinion of this minimal level of "understanding", it is the writer's contention that an understanding of the "conventions" and the "stereotypes" of a subject area provide the substance for refinement and an opportunity for a more profound understanding of the subject matter. Moreover, it is the writer's view that if a child cannot comprehend or retain the rudimentary conventions or stereotypes of some topic, then it is questionable that a comparable investment of time and energy at that particular stage in the cognitive growth of the child will enable him to acquire profound insights into the subject or demonstrate exceptional skills in coping with salient problems in the subject area.

In a related study, Smith (69 ) has suggested that if a pupil understands a test question and the appropriate (conventional) answer to that question, then that understanding may be asserted as a proposition or test item generalization. The relationship between the test item proposition and its corresponding generalization is illustrated in Table 1.

It should be evident that there are many statements or propositions which may be subsumed under the generalization stated in Table 1. If a pupil responds correctly (selects choice "a") to the test question in Table 1 then we may assert the corresponding test item

Table 1 RELATION OF TEST ITEM TO GENERALIZATION INCLUDED IN UNIT OF INSTRUCTION

---

1. Generalization: Work is done when a force moves an object through some distance.

2. Test Question: In which of the following examples is no work done?

   a. Pencil lays on desk.
   b. Pencil is used to write on paper.
   c. Pencil is thrown at wall.
   d. Pencil falls off table.

3. Test Item Generalization: If a pencil lays on a desk, then the pencil is not doing work upon the desk.

---

generalization, and this accurate response provides merely one slender piece of evidence that the pupil has some meaningful understanding of the generalization. Indeed, any test item is merely one member of a very large set of questions which might have been asked. A discussion of this relationship of the multiple-choice question to the ideas included in the unit plans is expanded in the Appendix G.

Before and after instruction of each unit, the test items were administered to a pilot class and the pupils' responses were used as the basis of an item analysis. Improvement of the response options consisted essentially of identifying those distractors in a multiple-choice question which were selected by 0 to 5% of the 35 pupils in the pilot group. When these low level distractors were identified, they were replaced by options judged by the researcher to be more plausible distractors. However, the limitation of time prevented the researcher from collecting empirical evidence to test his judgement in making these revisions.

B. Estimates of Validity. The validity of the test items as appropriate estimates of the generalizations included in the units of instruction was established upon the judgements of the three consultants to the project, i.e., a university physicist, a science supervisor, and a science teacher. Their judgement enabled the researcher to establish the content or face validity of the unit achievement tests.

Each test item was written directly underneath the generalization to which it corresponded. The listing of generalizations and test items was sent to each consultant with the request that he check each test item for the following considerations: 1) In your judgement does the test item provide an acceptable estimate of pupils' understanding of its corresponding generalization? 2) Are the possible answers acceptable and do you agree with the selection of the "preferred" answer for each question?

The researcher met with the consultants to discuss the test items or their written comments were used to revise or eliminate test items. However, the researcher must assume the responsibility for any errors or inappropriate questions or responses in any of the unit achievement tests.

In attempting to establish concurrent validity of the unit achievement tests, the researcher was concerned with the major skills required by those tests. It was apparent that the test questions and their responses relied strongly upon success in processing information via verbal symbols. That is, the unit tests favored those persons who were proficient in expressing their ideas or receiving ideas via written symbols or spoken symbols. It would not provide opportunity for pupils skilled in handicraft or proficient in expressing their ideas with tangible objects or materials. Therefore, it was inferred that pupils who did well on the unit achievement tests would also do well in tests of reading comprehension and measures of verbal intelligence.

In addition, pupils' success on the unit achievement tests would presumably be reflected in a similar level of success on a science achievement test which also relied predominantly upon written symbols. The Stanford Intermediate and Advanced Science Achievement Test provided an estimate of pupils' background of information about science topics and it relied strongly upon the use of reading proficiency on the part of the pupil taking the test.

The correlations between the unit achievement tests and the Stanford Reading Comprehension Test (34 ), the Lorge-Thorndike Verbal Intelligence Test (44 ), and the Stanford Intermediate and Advanced Science Achievement Test (33 ) are shown in Table 17. As expected, there was a high, positive correlation between success on the unit achievement tests and success on these standardized measures of verbal intelligence and achievement in reading comprehension and science background. This high relationship provided supporting evidence of the concurrent validity of the unit achievement tests.

C. Administering Unit Achievement Tests. When the unit tests were administered to pupils participating in the study, the test administrator read the test items aloud to the pupils taking the test. The pupils also had a copy of the test at their desks and separate answer sheets which they marked to indicate their preferred answer to a question. The test administrator read each question and the possible answers aloud and waited about 15 to 20 seconds for the pupils to mark their answer sheets. The pupils were encouraged not to guess wildly at answers. These instructions gave the pupil the opportunity to indicate which questions he did not understand and to indicate this on his answer sheet. In part, the directions to the pupils stated:

"You are not expected to know all of the answers to these questions about (electricity). Don't feel bad if you don't know some of the correct answers. The purpose of this test is to find out how much boys and girls in the elementary schools know about (electricity) (after) they have studied it in school. DO NOT GUESS WILDLY. If you do not know the answer to a question, skip over that question and go on to the next one.

You will not know all of the words in the test. I will read the questions and possible answers with you. This is done to help you with some of the hard words. Wait until the questions and answers have been read then select the correct answer if you know it. If you do not know the correct answer you may darken the space under answer number five (for that question to indicate that you realize that you do not know the answer to that question)."

The tests were administered by research assistants, while the classroom teacher was not present in the room. The teachers did not see the test questions before or after instruction. Moreover, they had agreed not to discuss the test questions or possible answers with their pupils at any time during the study. A copy of the schedule for administering the tests is shown in Appendix J.

There are two occasions when the classroom teacher did administer a unit achievement test. In the first instance, the teacher in School #5 administered the Heat Retention Test to his pupils in November, 1966, because the researcher was unable to have a research assistant at the school at the time when the pupils were ready to be tested.

The second exception occurred in the administration of the Heat Retention Test to pupils in the sixth grade in suburban School #7. These pupils had been promoted to a junior high school after all instruction had ended. At the request of the science department chairman, the science teachers in the junior high school administered the Heat Retention Test to these pupils rather than the project's research assistant. This was a matter of administrative convenience for the teachers in the junior high school

A mnemonic device was used to identify each unit achievement test and to indicate when it was administered to pupils in the sample. The letters (M,E,H) correspond to the tests for machines, electricity, and heat. A number after each letter indicated whether the test was administered before instruction (M1, E1, H1), directly after instruction had ended (M2, E2, H2), or as a retention test (M3, E3, H3) conducted three to five months after instruction had concluded.

D. Scoring Pupils' Answer Sheets. Each pupil had responded to the test questions by marking a separate answer sheet. This sheet was examined by research assistants to identify improper markings or other random errors which might have occurred. In those situations where two responses were given to the same question, the pupil's answer was not counted for that question. In those rare situations where a pupil had been unable to participate in the test situation, the pupil's answer sheet was discarded from the study. It was assumed that a pupil's inability to respond to the test question indicated clearly that whatever score or set of scores might be attained for that pupil, they would not provide a fair or reasonably accurate indication of his understanding of the topic being tested.

For example, since each question was read aloud to the pupils and they were to respond to the question while the test administrator waited for them to respond, a large number of blank spaces at the beginning or the end of a test answer sheet would indicate that the pupil was uncertain or unable to participate in the test situation. Other reasons for discarding an answer sheet from the analysis of data would include situations in which the pupil did not put his name onto the answer sheet, the pupil caused disruptive behavior in the classroom during testing, the pupil was unable to keep up with the rest of the class in taking the test, or the pupil had to leave the classroom before the test was completed. The incidence of these events of removing answer sheets from the test population was less than one-half of one per cent of the pupils tested at any single test period.

The pupils' answer sheets were scanned visually by a research assistant for possible errors and the research assistant assigned an identification number as well as a group number to each pupil. The answer sheets were optically scanned, scored, and an IBM card was punched for each answer sheet. During this scoring by machine, the operator checked each response on the first sheet and last sheet of the entire group of answer sheets to check for faulty machine operation. Random checks of pupils' answer sheets and IBM cards were made by research assistants for approximatly one per cent of the entire group of tests. The IBM card became the input medium for the computer programs to score and analyze data for each test.

E. Double Precision Scoring. In previous research, the investigator (74) had conducted item analyses of pupils' responses to test items about light energy. He had argued that the per cent correct responses to a test item provided a probability estimate of a pupil's understanding of the corresponding generalization. The improvement in the information processing capability of the Wayne State University computer has persuaded the researcher to extend the item analyses of the unit achievement tests to indicate which questions were answered correctly on the pre-test and on the post-test as well as those answered correctly on the post-test and on the retention test, which was administered three to five months after instruction ended. This rather conservative requirement has been labeled by the researcher "double precision scoring". An argument in defense of this scoring and item analysis procedure is presented in Appendix G.

In order for a pupil to be credited with a correct response under "double precision" scoring for the pre-test, he must choose the same correct response on the pre-test (M1, E1, H1) and the same correct response to the same test item on the post-test (M2, E2, H2). This indicated that the pupil understood the question and the correct answer before instruction and retained that understanding after instruction had ended. It is estimated that the liklihood of guessing this identical response purely on the basis of chance is approximately 1/16. An argument in favor of this interpretation has been presented in Appendix G.

In order for a pupil to be credited with a correct response under "double precision" scoring for the post-test, he must choose the correct response on the post-test (M2, E2, H2) and the same correct response to the same test item on the retention test (M3, H3, E3) administered three to five months after instruction had concluded. A correct response under these conditions indicated that the pupil understood the question and the correct answer and he retained this understanding for at least three months. The liklihood of a pupil guessing the identical answer to the same question is also estimated to be about 1/16.

Another mnemonic device was used to indicate"double precision" scoring. The double precision pre-test scores for machines, electricity, and heat have been indicated by the expression (M12, E12, H12). The double precision post-test scores have been indicated by the expressions (M23, E23, H23).

It is interesting to note that this procedure of "double precision" scoring was not mentioned in the original proposal for this project. The computer facilities which this type of scoring required were not available to the researcher at the time the proposal was initiated. Indeed, the researcher had not conceived of this procedure of scoring when he undertook the study. In other words, the technique for "double precision" scoring was a product of the research undertaken in this project and is considered by the researcher to be an important artifact of the project.

F. Estimating Reliability of Unit Achievement Test. As Guilford ( 27 ) has indicated, the formulas which are used to compute reliability of tests depend upon the variance among the test items. When there is a large number of test items which are not close to the optimum discriminating level of 50%, then the standard reliability formulas are inappropriate.

Figure 3 indicates the per cent correct responses for grade 6 pupils to the (M23) test. Similar patterns of responses were found for the other grade levels and for the other unit achievement tests. It is apparent from Figure 3 that the proportions for these unit achievement tests extended from 4% to 82% correct responses. Therefore, the conventional procedures for computing test reliability seemed inappropriate for the unit achievement tests.

The researcher elected to use the information processing power of the computer to simulate predictions of pupils' correct responses and to compare those predicted responses with the pupils' actual responses. This procedure is a form of the Monte Carlo Method described by McCracken (46 ) and by Kershner (39 ). However, as far as the writer can determine, it has not previously been applied to estimating test reliability. It must also be considered an important artifact of the project.

The procedure started with the selection of three pupils at random from each fourth grade class of pupils who had taken the pretest for simple machines (M12). This was about 40 pupils. The per cent correct responses for this entire grade group had previously been computed for each item on the (M12) test. The researcher wrote a computer program which would do the following tasks: 1) compute a random number (r) between 0% and 99%, 2) compare the random number with the proportions of pupils (p) responding correctly to the first test item, 3) if $p \geq r$, estimate that the pupil responded correctly, If $p < r$, then estimate that the pupil responded incorrectly, 4) repeat step number 3 for each of the fifty items on the test to which the pupils responded, 5) determine the number of accurate guesses for each pupil, 6) compute the per cent of accurate guesses that were made by the Monte Carlo procedure, 7) repeat the same procedure for the entire sample of pupils. Appendix G includes a simplified flowchart which illustrates this Monte Carlo simulation of test reliability.

Since there were 50 responses made by each pupil in the sample of 40 pupils on the (M12) test, the sample made a total of 2000 responses. For each pupil, it was possible to compute the per cent accurate guesses made by the Monte Carlo procedure. The per cent of correct guesses was selected as the best estimate of the accuracy of the (M12) test for predicting success of other fourth grade pupils in responding to the (M12) test.

This per cent of correct predictions (P), was used as a coefficient of determination (d) which was described by Guilford (27 ).

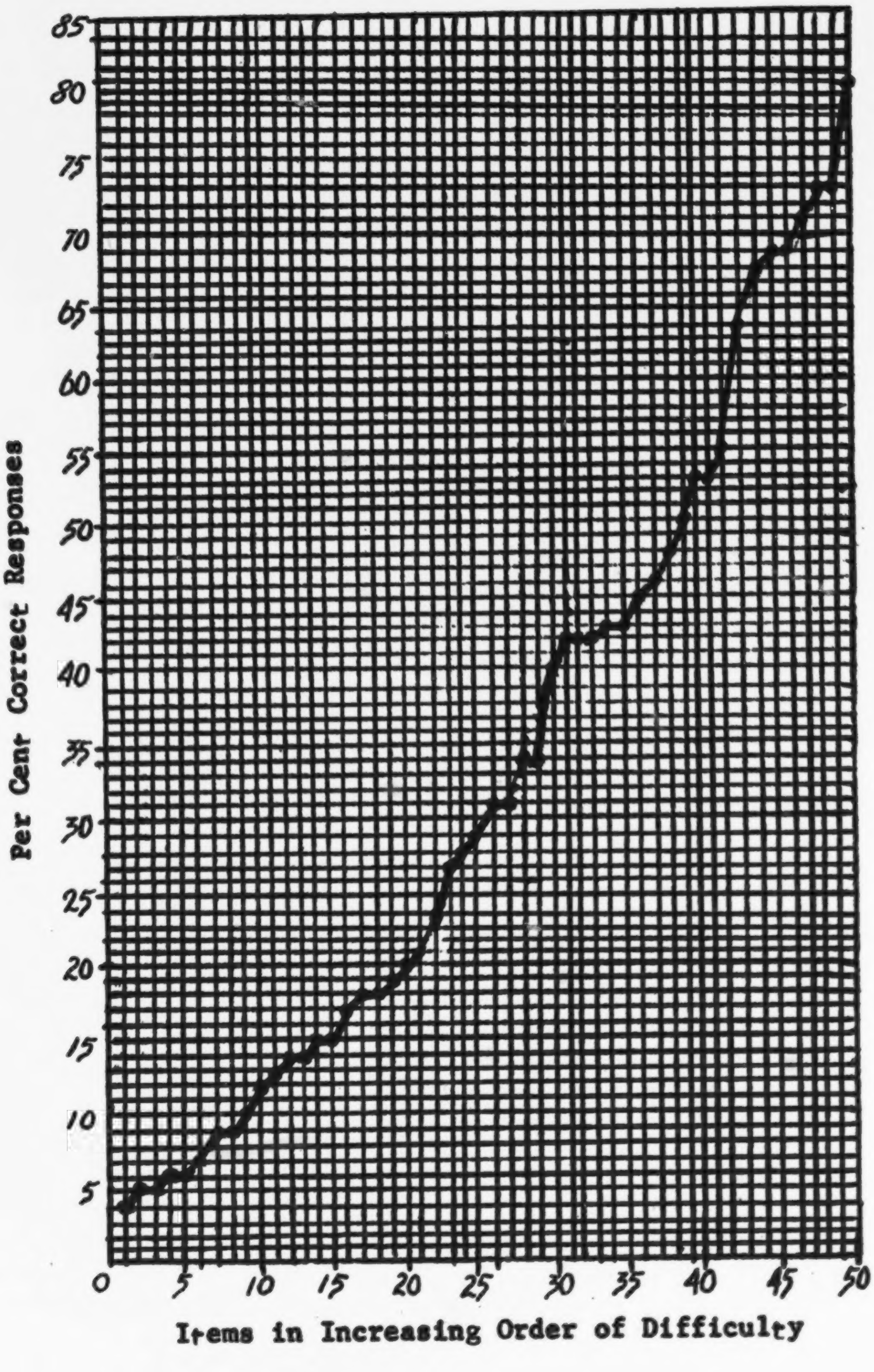


Figure 3 Per Cent Correct Responses of Grade 6 Pupils to Machines Post-Test (M23)

It was used in the following expressions:

$$(\text{coefficient of determination}) = (\text{correlation coefficient})^2$$

$$d = r^2$$

$$d = P$$

$$P = r^2$$

$$\sqrt{P} = r$$

to provide a correlation coefficient to estimate the reliability of the (M12) test when it was used with other samples of fourth grade pupils in the population. A similar procedure was followed to compute the reliability coefficients for fifth and sixth grade pupils as well as the reliability coefficients for random samples of fourth, fifth, and sixth grade pupils for each of the unit achievement tests. These reliability coefficients for single precision scoring (M1, M2, M3,...H1, H2, H3) and for double precision scoring (M12, M23, ...H12, H23) are shown in Table 2.

G. Standardized Tests and Other Measures. The following standardized tests were used to obtain estimates of the verbal intelligence, reading proficiency, and background of science information of the pupils: Lorge-Thorndike Verbal Intelligence Test (level 3), Stanford Paragraph Meaning Test (form JM), and Stanford Intermediate and Advanced Science Achievement Test (form JM).

One of the indicators of socio-economic status was occupation of the chief wage earner in each pupil's family. Each pupil was asked to identify the occupation of the father and the mother if she was employed. This occupational label was compared with the U.S. Office of Labor Classification Guide (19 ) in order to classify the occupation of the parents as one of the following categories: professional, managerial, sales, service, skilled, semi-skilled, unskilled, parents' occupation unknown. Bar graphs in Appendix E show distributions of the occupational status of the chief wage earners in the families of pupils in the cooperating schools.

Additional information regarding the socio-economic background of each class or school population was provided by bulletins from the Promotion and Research Department of the Detroit News (61 ) and the United Community Services of Metropolitan Detroit (78 ). These reports included 1962 estimates and 1960 census data with maps indicating population growth, home ownership, and income in the Detroit Standard Metropolitan Statistical Area in the three counties of Machom, Oakland, and Wayne. This information indicated the median family income, median home value, per cent homes owned, and rent rate for homes in the community served by each of the schools in the study.

Table 3 summarizes some of these socio-economic characteristics. The last column identifies the overall socio-economic rating for the community served by each school. It indicates that the low

Table 2 RELIABILITY COEFFICIENTS OF SINGLE PRECISION AND DOUBLE PRECISION SCORING OF UNIT ACHIEVEMENT TESTS FOR GRADE GROUPS*

| | Machines Test | | | | | Electricity Test | | | | | Heat Test | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Single Precision | | | Dbl Prec | | Single Precision | | | Dbl Prec | | Single Precision | | | Dbl Prec | |
| | M1 | M2 | M3 | M12 | M23 | E1 | E2 | E3 | E12 | E23 | H1 | H2 | H3 | H12 | H23 |
| Grade 6 Coeffic. | 79 | 76 | 73 | 81 | 81 | 76 | 75 | 74 | 83 | 81 | 77 | 79 | 77 | 82 | 80 |
| No. Pupils | 40 | 40 | 40 | 51 | 48 | 40 | 40 | 40 | 48 | 51 | 40 | 40 | 40 | 48 | 48 |
| Grade 5 Coeffic. | 75 | 76 | 76 | 84 | 81 | 81 | 71 | 76 | 86 | 82 | 79 | 79 | 81 | 84 | 80 |
| No. Pupils | 40 | 40 | 40 | 45 | 39 | 40 | 40 | 40 | 39 | 42 | 40 | 40 | 40 | 39 | 39 |
| Grade 4 Coeffic. | 81 | 71 | 76 | 87 | 84 | 71 | 76 | 78 | 87 | 86 | 79 | 76 | 75 | 85 | 81 |
| No. Pupils | 40 | 40 | 40 | 21 | 21 | 40 | 40 | 40 | 21 | 21 | 40 | 40 | 40 | 21 | 18 |

*A reliability coefficient of .81 was estimated for the (M12) test at grade 6 using a random sample of 51 pupils. All coefficients are positive 2-digit numerals with a decimal point understood to precede the coefficient.

Table 3 SOCIO-ECONOMIC CHARACTERISTICS OF COMMUNITIES SERVED BY SCHOOLS IN STUDY

| | POPULATION | 1962 DENSITY | | ECONOMIC CHARACTERISTICS | | | Soc-* |
|---|---|---|---|---|---|---|---|
| Detroit Schools | 1960 Census | Persons Per Dwelling | Persons Per Sq. Mi. | %Homes Owned | 1960 Median Home Value | Fam. Income 1959 Median | Econ Rating |
| School #1<br>(Sub-Community 16C) | 18,389 | 4.1 | 7,669 | 79 | 11,500 | 5,400 | 1 |
| School #2<br>(Sub-Community 8C) | 33,625 | 3.3 | 12,888 | 82 | 13,200 | 7,200 | 3 |
| School #3<br>(Sub-Community 11B) | 43,712 | 3.0 | 11,179 | 80 | 14,200 | 8,100 | 4 |
| School #4<br>(Sub-Community 9C) | 48,909 | 3.2 | 11,547 | 74 | 10,300 | 6,500 | 2 |
| School #5<br>(Sub-Community 6C) | 28,613 | 3.8 | 20,333 | 55 | 8,900 | 4,800 | 1 |
| Suburban Schools | | | | | | | |
| School #6<br>(Lincoln Park, Mich.) | 53,933 | 3.7 | 9,341 | 87 | 12,000 | 7,100 | 3 |
| School #7<br>School #8<br>(Southfield, Mich.) | 31,501 | 3.6 | 1,335 | 93 | 18,700 | 8,400 | 5 |

*Socio-Economic rating is based on a scale of 1 through 5, in which 1 indicates the lowest level. Source: *Social Rating of Communities in the Detroit Area*. Detroit: United Community Services of Metropolitan Detroit. (98) and Promotion and Research Department of the Detroit News (61).

socio economic category included pupils in schools #1 and #5. These were schools having predominatly Negro pupil populations.

The middle socio-economic classification included pupils from three Detroit Schools (#2, #3, #4) and one suburban school (#6).

The high socio-economic category included pupils from two suburban schools (#7, #8).

H. Graphical Analysis of Test Data. Each of the classes participating in the study was examined for each of the test variables to determine if the distribution of the double precision test scores was normal or skewed. For each test variable, the cumulative frequency was tabulated for each class and the cumulative per cent was determined. This cumulative per cent was used to plot a line on a normal probability paper. If the point fell along a straight line drawn by the researcher, then the class' distribution of scores for that variable was considered to be normal. This is illustrated in Figure 4. If the distribution did not fall along a straight line, then the cumulative per cent was plotted on a skewed probability paper following the skewed distribution developed by Bumbel ( 26) and the special probability paper suggested by Powell ( 62). This is illustrated in Figure 5.

In the case of group scores which clearly conformed to a normal distribution, it was possible to use this straight line to indicate the mean or median, standard deviation, and average rate of change. This is illustrated in Figure 4. In those situations where the distribution was skewed, it was possible to estimate the median value and the average rate of change for the distribution as shown in Figure 5. It seemed to the researcher that this graphical procedure had certain advantages over the exclusive use of numerical methods e.g., least squares, analysis of variance.

The average rate of change indicated the average variation which was made for different proportions of each class. It was possible to compare the slopes of different classes or school populations and to note the displacement of the curve of different groups on the same test variable. It was possible to compare slopes and displacements of the lines for different tests which were taken by the same group of pupils. In other words, the graphical procedure provided additional information which may have been obscured by simply calculating the standard statistical parameters and conducting the standard tests for significant differences or significant correlations among the variables.

Appendix H contains an additional discussion of the graphical analysis which was conducted to examine changes in distribution of scores from pre-test to post-test and to examine changes in the median value and the slopes of curves in which the normal distribution provided a good fit for the pre-test scores or the post-test

Figure 4 TYPICAL GRAPH OF CLASS SCORES USING NORMAL PROBABILITY PAPER

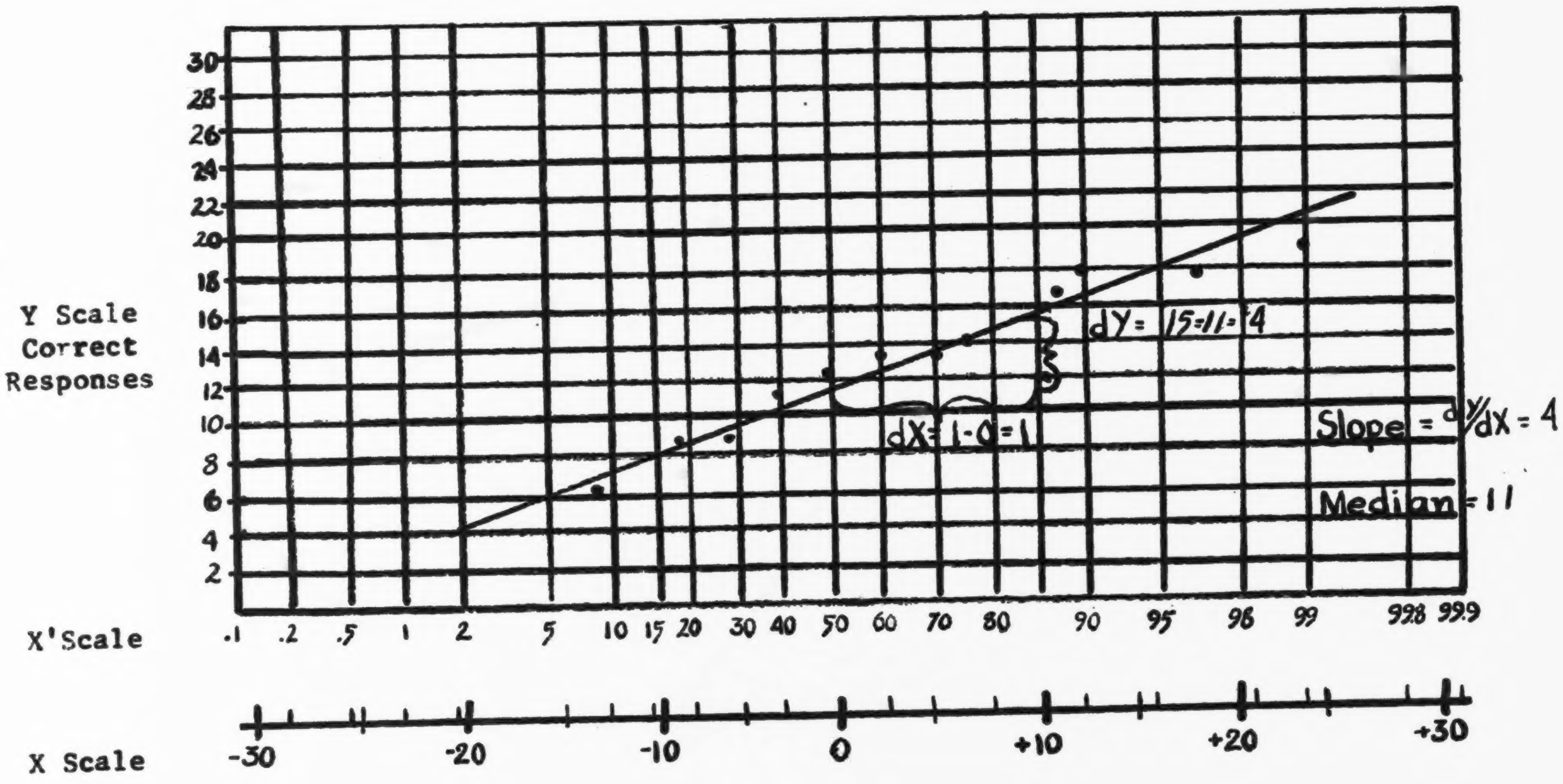
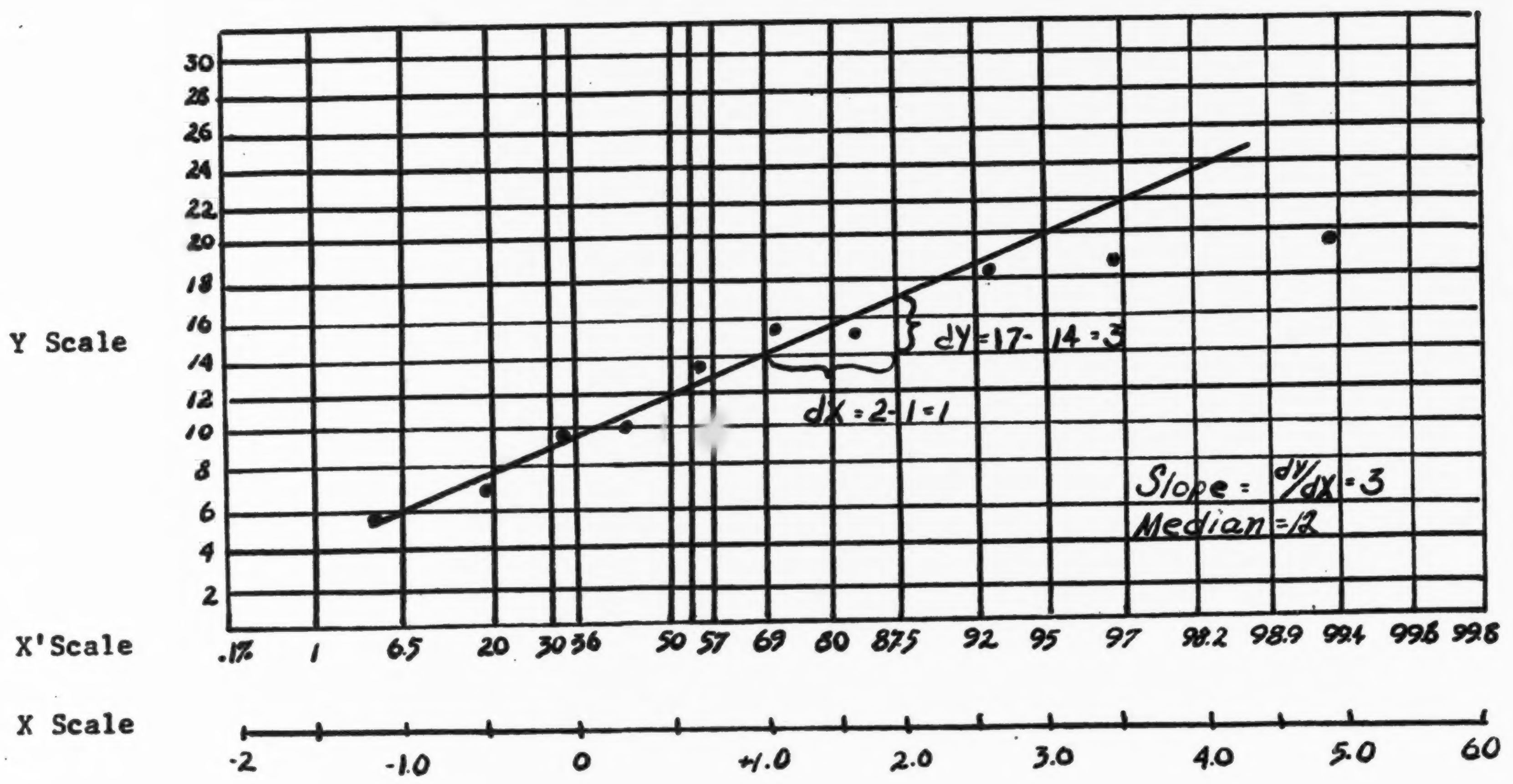


Figure 5 TYPICAL GRAPH OF CLASS SCORES USING SKEWED PROBABILITY PAPER



scores.

I. Statistical Analysis of the Data. Significant differences among groups were identified by means of analysis of variance. These calculations were completed with the assistance of the TSAR library of sub-routines, Wayne State University Computing Center (85 ). Essentially the analysis of variance sub-routines were based upon models described by Lindquist (41 ).

Bartlett's formula (41 ) was used to test for homogeneity of variances among classes at each grade level for each double precision scored unit achievement test. The numerical value computed by Bartlett's procedure was compared with the appropriate chi-square value in order to test the null hypothesis at the 1% level of confidence.

Pearson product moment correlation analysis was used to identify correlations among the variables included in the study. The TSAR sub-routines were also used for the correlations analysis. These sub-routines were based upon models reported by Walker and Lev (89 ).

Appendix H indicates the statistical formulas used in computing the analysis of variance and the correlation coefficients.

J. Item Analysis of Unit Achievement Tests. An item analysis of each unit achievement test was conducted using the double precision scores for all pupils in the study. The first item analysis was conducted for all pupils according to their official grade assignment, i.e., grade four, grade five, grade six. All pupils were classified according to that official school grade assignment. An item analysis of each unit achievement test provided an estimate of the success of those pupils in responding correctly to each test item on the unit achievement test before instruction (M12, E12, H12) as well as another estimate of their success in responding correctly to the test item after instruction (M23, E23, H23). This information provided a basis for inferring that the corresponding science generalization would be understood by the pupils in that particular grade level.

TAbles showing the probable success of a pupil in each grade level understanding each generalization and its corresponding test item generalization are included in Appendices A, B, C for the respective topics of simple machines, electricity, and heat.

It was inferred that a more precise estimate of probable success for any pupil could be obtained by utilizing other information about the pupils, e.g., background of science information, reading level, verbal intelligence, socio-economic level. It was assumed that many schools would have this information available and could profitably use this refined information.

The same item analysis was conducted for all pupils who had completed the Stanford Intermediate and Advanced Achievement Test. The publisher's norms were used to classify all pupils in the study into quartile 1 or below (low 25%), between quartile 1 and quartile 3 (middle 50%), and those above quartile 3 (top 25%). An item analysis of the same double precision test scores for each unit achievement test provided estimates of the probable success of pupils in each grade group and either low, middle, or high categories of science achievement to understand each of the test item generalizations. These estimates are also shown in the tables in Appendices A, B, C.

Similar item analyses were conducted for the low 25%, the middle 50%, and the high 25% of the pupils in the study according to the reading comprehension norms of the test publisher. A third item analysis was conducted for the low 25%, the middle 50%, and the high 25% using the verbal intelligence test norms of the publisher.

The socio-economic category specified in Table 4 was used to classify all pupils in the sample according to low, middle, and high socio-economic level. A fifth item analysis was conducted to produce probability estimates of the success of the pupils in the low, middle, and high socio-economic communities in grades 4, 5, and 6 to understand each test item generalization.

The estimates which utilized measures of pupils' reading comprehension, verbal intelligence, and socio-economic level have also been reported in the tables in Appendices A, B, C.

It was possible to estimate the levels of confidence which one could place in each of the proportions listed in Appendices A, B, C, by using the graph provided by Tate and Clelland ( 83).and reported with their permission in Appendix D. Since each appendix indicated the number of pupils used in calculating each proportion, the Tate and Clelland figure may be used to estimate the probable error of each proportion and the reader may be 90% confident in the accuracy of that estimate. It should be noted that these estimates apply to other members of the population defined for this study.

## III. RESULTS OF STUDY

### 1. Analysis of Variance for Unit Achievement Test

A. Results for Grade Four. Tables 4,5,6 provide summary statements of the results of the analysis of variance conducted for grade four classes. Additional details may be found in Appendix H.

1. Machines Pre-Test (M12) - There were no significant differences among the variances of the classes in the Grade 4 portion of the sample, as indicated by Bartlett's Test. F Test did not indicate significant differences among the fourth grade classes. Class #9 scored highest on the preliminary test and class #19 scored lowest.

2. Machines Post-Test (M23) - The Bartlett's Test revealed no significant differences among the variances of the fourth grade classes. When T Tests were conducted between pairs of classes, the significant differences at the 1% level of confidence were attributed to differences between low-scoring classes (#10,19, 20,23) and the high-scoring classes (#9,24,38).

It is interesting to note that classes #9 and #10 began instruction without significant differences between them and both classes received instruction from the same science specialist in the school #2 for equivalent amounts of time. However, they concluded their study of simple machines by making scores which were significantly different.

3. Electricity Pre-Test (E12) - The Bartlett's Test indicated that there were significant differences among the fourth grade classes at the 1% level of confidence. An F Test was made between the low-scoring classes (#19,20,24) and the high-scoring classes (#9,10,38).

Classes #19 and #20 entered instruction for electricity with low scores which suggested weak preparation in comparison to the other classes in the sample. These two classes had scored significantly lower than the other fourth grade classes on the (M23) test and these pupils were from low socio-economic communities. On the other hand, class #24 was located in a middle socioeconomic community and it also scored low.

4. Electricity Post-Test (E23) - The Bartlett's Test indicated that there was a significant difference among the variances of classes in the fourth grade group. F Tests were donducted between the pairs of classes and indicated that the significant differences could be attributed to the low-scoring classes (#19,

Table 4 SUMMARY OF ANALYSIS OF VARIANCE RESULTS FOR MACHINES PRE-TEST (M12) AND POST-TEST (M23) FOR GRADE 4 PUPILS

| | | Comparison List of Classes | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 19 | 20 | 23 | 24 | 38 |
| (M12) | | | | | | | |
| | 9 | NS | NS | NS | NS | NS | NS |
| Main | 10 | | NS | NS | NS | NS | NS |
| List | 19 | | | NS | NS | NS | NS |
| of | 20 | | | | NS | NS | NS |
| Classes | 23 | | | | | NS | NS |
| | 24 | | | | | | NS |
| (M23) | | | | | | | |
| | 9 | H | H | H | H | NS | NS |
| Main | 10 | | NS | NS | NS | NS | L |
| List | 19 | | | NS | NS | NS | NS |
| of | 20 | | | | NS | L | L |
| Classes | 23 | | | | | NS | NS |
| | 24 | | | | | | NS |

Bartlett's Test--Not Significant for (M12), Significant for (M23)
F Test-- Significant for (M12) or Significant for (M23)

Legend: "H" indicates class on vertical axis scored significantly higher than comparison class listed on horizontal axis. "L" indicates class on vertical axis scored significantly lower than comparison class listed on horizontal axis. "NS" indicates that class was not significantly different than class listed on horizontal axis. The table indicates that class 9 scored significantly higher than class 10 on the (M23) test.

## Table 5 SUMMARY OF ANALYSIS OF VARIANCE RESULTS FOR ELECTRICITY PRE-TEST (E12) AND POST-TEST (E23) FOR GRADE 4 PUPILS

| | | Comparison List of Classes | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 19 | 20 | 23 | 24 | 38 |
| **(E12)** | | | | | | | |
| | 9 | NS | H | H | NS | H | NS |
| Main | 10 | | NS | NS | NS | NS | NS |
| List | 19 | | | NS | NS | NS | L |
| of | 20 | | | | NS | NS | NS |
| Classes | 23 | | | | | NS | NS |
| | 24 | | | | | | L |
| **(E23)** | | | | | | | |
| | 9 | NS | H | H | H | H | H |
| Main | 10 | | H | H | NS | NS | NS |
| List | 19 | | | NS | NS | NS | L |
| of | 20 | | | | NS | NS | NS |
| Classes | 23 | | | | | NS | NS |
| | 24 | | | | | | NS |

Bartlett's Test--Significant for (E12) and for (E23)
F Test--Significant for (E12) and for (E23)

Legend: "H" indicates class on vertical axis scored significantly higher than comparison class listed on horizontal axis. "L" indicates class on vertical axis scored significantly lower than comparison class listed on horizontal axis. "NS" indicates that class was not significantly different than class listed on horizontal axis. The table indicates that class 9 scored significantly higher than class 20 on the (E12) test.

Table 6 SUMMARY OF ANALYSIS OF VARIANCE RESULTS FOR HEAT PRE-TEST (H12) AND POST-TEST (H23) FOR GRADE 4 PUPILS

| | | Comparison List of Classes | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 | 19 | 20 | 23 | 24 | 38 |
| (H12) | 9 | NS | H | H | NS | NS | NS |
| Main | 10 | | H | H | NS | NS | NS |
| List | 19 | | | NS | NS | NS | NS |
| of | 20 | | | | NS | NS | NS |
| Classes | 23 | | | | | NS | NS |
| | 24 | | | | | | NS |
| (H23) | 9 | H | H | H | NS | H | NS |
| Main | 10 | | H | H | NS | NS | NS |
| List | 19 | | | NS | L | L | L |
| of | 20 | | | | L | NS | L |
| Classes | 23 | | | | | NS | NS |
| | 24 | | | | | | NS |

Bartlett's Test--Not Significant on (H23), Significant on (H12)
F Test--Significant on (H12) and on (H23)

Legend: "H" indicates class on vertical axis scored significantly higher than comparison class listed on horizontal axis. "L" indicates class on vertical axis scored significantly lower than comparison class listed on horizontal axis. "NS" indicates that class was not significantly different than class listed on horizontal axis. Class 9 scored significantly higher than class 10 on the (H23) test.

20) and the high-scoring classes (#9,10,38).

It should be noted that classes #19 and #20 were significantly low at the start of instruction as indicated by their scores on the (E12) test, and they did not make significant improvements after instruction had concluded. They continued to remain significantly below other fourth grade classes. Moreover, class #19 did not make substantial improvement from the pre-test to the post-test for the identical pupils in that class.

Graphical analysis of the (E23) test supported the impression stated in the preceding paragraph. This analysis indicated that the median scores and the slopes of graphs for the two classes did not change appreciably for either class. In contrast, class #24 improved to a relative standing so that it was not significantly lower than any other grade four class, except class #9 which scored substantially higher than all other grade four classes.

5. Heat Pre-Test (H12) - The Bartlett's Test revealed significant differences among the pupils' scores on the (H12) test. F Tests indicated that these differences could be attributed to the low scores made by classes (#19,20) as compared to the high-scoring classes (#9,10).

6. Heat Post-Test (H23) - The Bartlett's Test did not reveal significant differences among the variances for the (H23) test. F Tests revealed significant differences at the 1% level of confidence. T Tests indicated that these differences were attributed to the low scores made by classes (#19,20). Once again, class #9 distinguished itself by scoring significantly higher than class #19 and #20, as well as classes #10 and #24.

B. Results for Grade Five Classes. Tables 7,8,9 provide summary statements of the results of the analysis of variance conducted for grade five classes. Additional details may be found in Appendix H.

1. Machines Pre-Test (M12) - The Bartlett's Test indicated that the variances among the classes in grade five were not homogeneous. F Tests indicated that the differences could be attributed to the low-scoring classes (#1,21), and the high-scoring classes (#2,11, 12,26,32,39).

2. Machines Post-Test (M23) - The Bartlett's Test did not indicate significant differences in the variances of the fifth grade groups on the (M23) test. F Tests indicated that there were significant differences and subsequent T Tests showed that the differences could be attributed to low scores made by classes (#2,16,21), while significantly higher scores were made by classes (#12,15,32, 39). It is interesting to note that class #21 began instruction

Table 7 SUMMARY OF ANALYSIS OF VARIANCE RESULTS FOR MACHINES PRE-TEST (M12) AND POST-TEST (M23) FOR GRADE 5 PUPILS

| | Comparison List of Classes | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **(M12)** Main Listof Classes | 2 | 6 | 11 | 12 | 15 | 16 | 21 | 25 | 26 | 32 | 33 | 34 | 39 |
| 1 | L | NS | L | L | NS | NS | NS | NS | L | L | NS | NS | L |
| 2 | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 6 | | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 11 | | | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 12 | | | | | NS | NS | H | NS | NS | NS | NS | NS | NS |
| 15 | | | | | | NS | NS | NS | NS | NS | NS | NS | NS |
| 16 | | | | | | | NS | NS | NS | NS | NS | NS | NS |
| 21 | | | | | | | | NS | NS | L | NS | NS | L |
| 25 | | | | | | | | | NS | NS | NS | NS | NS |
| 26 | | | | | | | | | | NS | NS | NS | NS |
| 32 | | | | | | | | | | | NS | NS | NS |
| 33 | | | | | | | | | | | | NS | NS |
| 34 | | | | | | | | | | | | | NS |
| **(M23)** Main List of Classes | | | | | | | | | | | | | |
| 2 | | NS | NS | NS | NS | NS | NS | NS | NS | L | NS | NS | NS |
| 6 | | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 11 | | | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 12 | | | | | NS | H | H | NS | NS | NS | NS | NS | NS |
| 15 | | | | | | H | NS | NS | NS | NS | NS | NS | NS |
| 16 | | | | | | | NS | NS | NS | L | NS | NS | L |
| 21 | | | | | | | | NS | NS | L | NS | NS | L |
| 25 | | | | | | | | | NS | NS | NS | NS | NS |
| 26 | | | | | | | | | | NS | NS | NS | NS |
| 32 | | | | | | | | | | | H | NS | NS |
| 33 | | | | | | | | | | | | NS | NS |
| 34 | | | | | | | | | | | | | NS |

Bartlett's Test--Not Significant for (M23), Significant for (M12)
F Test--Significant for (M12) and for (M23)

Legned: "H" indicates class on vertical axis scored significantly higher than comparison class listed on horizontal axis. "L" indicates class on vertical axis scored significantly lower than comparison class listed on horizontal axis. "NS" indicates that class was not significantly different than class listed on horizontal axis.

Table 8 SUMMARY OF ANALYSIS OF VARIANCE RESULTS FOR ELECTRICITY PRE-TEST (E12) AND POST-TEST (E23) FOR GRADE 5 PUPILS

| (E12) Main Listof Class. | Comparison List of Classes 6 | 11 | 12 | 15 | 16 | 21 | 25 | 26 | 32 | 33 | 34 | 39 | 55 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | NS | NS | NS | L | NS | NS | NS | NS | NS | NS | NS | NS | |
| 6 | | NS | NS | NS | NS | H | NS | NS | NS | NS | NS | NS | |
| 11 | | | NS | NS | NS | H | NS | NS | NS | NS | NS | NS | |
| 12 | | | | NS | NS | H | NS | NS | NS | NS | NS | NS | |
| 15 | | | | | H | H | NS | NS | NS | NS | H | H | |
| 16 | | | | | | NS | NS | NS | NS | NS | NS | NS | |
| 21 | | | | | | | L | L | L | NS | NS | NS | |
| 25 | | | | | | | | NS | NS | NS | NS | NS | |
| 26 | | | | | | | | | NS | NS | NS | NS | |
| 32 | | | | | | | | | | NS | NS | NS | |
| 33 | | | | | | | | | | | NS | NS | |
| 34 | | | | | | | | | | | | NS | |

| (E23) Main Listof Class. | 6 | 11 | 12 | 15 | 16 | 21 | 25 | 26 | 32 | 33 | 34 | 39 | 55 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | NS | NS | NS | NS | NS | H | NS | NS | NS | NS | NS | L | L |
| 6 | | NS | NS | NS | NS | H | NS | NS | NS | NS | NS | NS | NS |
| 11 | | | NS | NS | NS | H | NS | NS | NS | NS | NS | NS | NS |
| 12 | | | | NS | NS | H | NS | NS | NS | NS | NS | H | H |
| 15 | | | | | NS | H | NS | NS | NS | NS | NS | H | H |
| 16 | | | | | | H | NS | NS | NS | NS | NS | NS | NS |
| 21 | | | | | | | L | L | L | L | L | NS | NS |
| 25 | | | | | | | | NS | NS | NS | NS | NS | NS |
| 26 | | | | | | | | | NS | NS | NS | H | H |
| 32 | | | | | | | | | | NS | NS | H | NS |
| 33 | | | | | | | | | | | NS | NS | NS |
| 34 | | | | | | | | | | | | NS | NS |
| 39 | | | | | | | | | | | | | NS |

Bartlett's Test--Not Significant for (E12), Significant for (E23)
F Test--Significant for (E12) and Significant for (E23)

Legend: "H" indicates class on vertical axis scored significantly higher than comparison class listed on horizontal axis. "L" indicates class on vertical axis scored significantly lower than comparison class listed on horizontal axis. "NS" indicates that class was not significantly different than class listed on horizontal axis.

Table 9 SUMMARY OF ANALYSIS OF VARIANCE RESULTS FOR HEAT PRE-TEST (H12) AND POST-TEST (H23) FOR GRADE 5 PUPILS

|  | Comparison List of Classes |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (H12) Main List of Class | 6 | 11 | 12 | 15 | 16 | 21 | 25 | 26 | 32 | 33 | 34 | 39 |
| 2 | NS | NS | L | NS | NS | NS | NS | L | NS | NS | NS | NS |
| 6 |  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 11 |  |  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 12 |  |  |  | NS | H | H | NS | NS | NS | NS | NS | NS |
| 15 |  |  |  |  | NS | NS | NS | NS | NS | NS | NS | NS |
| 16 |  |  |  |  |  | NS | NS | L | NS | NS | NS | NS |
| 21 |  |  |  |  |  |  | NS | NS | NS | NS | NS | NS |
| 25 |  |  |  |  |  |  |  | NS | NS | NS | NS | NS |
| 26 |  |  |  |  |  |  |  |  | NS | NS | NS | NS |
| 32 |  |  |  |  |  |  |  |  |  | NS | NS | NS |
| 33 |  |  |  |  |  |  |  |  |  |  | NS | NS |
| 34 |  |  |  |  |  |  |  |  |  |  |  | NS |
| (H23) Main List of Class |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 | NS | NS | L | NS | NS | NS | NS | L | L | NS | NS | NS |
| 6 |  | NS | NS | NS | H | H | NS | NS | NS | NS | NS | NS |
| 11 |  |  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 12 |  |  |  | NS | H | H | NS | NS | NS | NS | NS | NS |
| 15 |  |  |  |  | NS | NS | NS | NS | NS | NS | NS | NS |
| 16 |  |  |  |  |  | NS | NS | L | L | L | NS | L |
| 21 |  |  |  |  |  |  | NS | L | L | NS | NS | NS |
| 25 |  |  |  |  |  |  |  | NS | NS | NS | NS | NS |
| 26 |  |  |  |  |  |  |  |  | NS | NS | NS | NS |
| 32 |  |  |  |  |  |  |  |  |  | NS | NS | NS |
| 33 |  |  |  |  |  |  |  |  |  |  | NS | NS |
| 34 |  |  |  |  |  |  |  |  |  |  |  | NS |

Bartlett's Test--Not Significant for (H12) or for (H23)
F Test--Significant for (H12) or for (H23)

Legend: "H" indicates class on vertical axis scored significantly higher than comparison class listed on horizontal axis. "L" indicates class on vertical axis scored significantly lower than comparison class listed on horizontal axis. "NS" indicates that class was not significantly different than class listed on horizontal axis.

with significantly low scores and concluded instruction with significantly low scores. It is also interesting to note that classes #12, 32, and 39 started instruction with significantly high pre-test scores, and concluded instruction with significantly higher post-test scores than the other fifth grade classes.

Graphical analysis had indicated that there were positively skewed distributions for classes (#32,34) and log-normal distributions for classes (#6,25,26). However these variations as revealed by the graphical analysis did not result in a rejection of the null hypothesis by the Bartlett's Test. Moreover, the positively skewed distributions for class #32 placed it significantly higher than other classes in the fifth grade group.

3. Electricity Pre-Test (E12) - The Bartlett's Test did not indicate that there was a significant difference in the variances of the fifth grade classes on this test. An F Test indicated significant differences among the classes, and subsequent T Tests identified significant differences between low-scoring classes (#2,21) and high-scoring classes (#6,11,12,15,26,32).

Graphical analysis had identified positively skewed distributions for classes (#12,26,33,34), but the skewed distributions did not cause these classes to be significantly lower than any of the other fifth grade classes on the (E12) test. On the contrary, classes #12 and #6 were significantly higher than some of the other grade five classes on the (E12) test.

4. Electricity Post-Test (E23) - The Bartlett's Test indicated that there was a significant difference among the variances of the classes in the grade five sample. F Tests were conducted between the pairs of classes and indicated that the differences were primarily due to low-scoring classes (#2,21) and high scores made by all other classes in the grade five sample. It is interesting to note that the F Test indicated that even class #2 was significantly different from class #21. It is also interesting to note that classes #39 and #55 made slightly higher mean scores than did class #2, but their variances were significantly different. Classes #12 and #15 made significantly higher mean scores than class #39 and #55, and their variances were also significantly different.

Classes (#6,16,32,33) had graphs which indicated positively skewed distirbutions of scores within these classes, but the F Tests did not indicate that they were significantly lower than most of the other fifth grade classes.

5. Heat Pre-Test (H12) - The Bartlett's Test did not indicate significant differences among classes in grade five on the (H12) test. An F Test revealed significant differences among these classes, and subsequent T Tests indicated that these differences could be attributed to low-scoring classes (#2,16) versus high-scoring classes (#12,26).

6. Heat Post-Test (H23) - The Bartlett's Test did not reveal significant differences among the variances of the grade five classes. An F Test did indicate significant differences among those classes, and T Tests revealed that the differences were attributable to the low scores made by classes (#2,16,21) versus the high-scoring classes (#6,12,26,32,33,39).

Graphical analysis had indicated that the distribution of the scores within classes #21 had changed from log-normal to positively skewed distributions. It also suggested that there was no substantial improvement made by these pupils as indicated by their median scores. However, some individuals within these classes did make substantial improvements.

C. Results for Grade Six Classes. Tables 10,11,12 provide summary statements of the results of the analysis of variance conducted for grade six classes. Additional details may be found in Appendix H.

1. Machines Pre-Test (M12) - The Bartlett's Test did not indicate that the variances among the classes were significantly different on the (M12) test. An F Test indicated that there were significant differences among those classes, and subsequent T Tests revealed that the significant differences could be attributed to low-scoring classes (#3,4,13,14,17,22,35,36) and the high-scoring classes (#7,8,28,40,41,58).

It is interesting to note that graphical analysis had indicated that group #88 was positively skewed, but the combination of F Test and T Test did not indicate that the skewed distribution made class #88 significantly lower than any of the other sixth grade classes. The skewed distribution merely indicated that there was an accumulation of relatively low scores within this particular class on the (M12) test.

2. Machines Post-Test (M23) - The Bartlett's Test did not reveal significant differences among the sixth grade classes. An F Test and subsequent T Tests did indicate significant differences between low-scoring classes (#3,4) and the high-scoring classes (#7,8,88,13,14,27,28,35,36,37,40,41,58). It should

## Table 10 SUMMARY OF ANALYSIS OF VARIANCE RESULTS FOR MACHINES PRE-TEST (M12) AND POST-TEST (M23) FOR GRADE 6 PUPILS

Comparison List of Classes

| Main List of Classes (M12) | 4 | 7 | 8 | 88 | 13 | 14 | 17 | 18 | 22 | 27 | 28 | 35 | 36 | 37 | 40 | 41 | 58 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | NS | NS | L | NS | NS | NS | NS | NS | NS | NS | L | NS | NS | NS | NS | NS | L |
| 4 | | NS | NS | NS | NS | NS | NS | NS | NS | NS | L | NS | NS | NS | NS | NS | NS |
| 7 | | | NS | NS | NS | NS | NS | NS | H | NS | NS | NS | NS | NS | NS | NS | NS |
| 8 | | | | NS | H | H | H | NS | H | NS | NS | H | H | NS | NS | NS | NS |
| 88 | | | | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 13 | | | | | | NS | NS | NS | NS | NS | L | NS | NS | NS | NS | NS | NS |
| 14 | | | | | | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 17 | | | | | | | | NS | NS | NS | NS | NS | NS | NS | NS | NS | L |
| 18 | | | | | | | | | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 22 | | | | | | | | | | NS | L | NS | NS | NS | L | L | L |
| 27 | | | | | | | | | | | NS | NS | NS | NS | NS | NS | NS |
| 28 | | | | | | | | | | | | NS | NS | NS | NS | NS | NS |
| 35 | | | | | | | | | | | | | NS | NS | NS | NS | NS |
| 36 | | | | | | | | | | | | | | NS | NS | NS | NS |
| 37 | | | | | | | | | | | | | | | NS | NS | NS |
| 40 | | | | | | | | | | | | | | | | NS | NS |
| 41 | | | | | | | | | | | | | | | | | NS |

| Main List of Classes (M23) | 4 | 7 | 8 | 88 | 13 | 14 | 17 | 18 | 22 | 27 | 28 | 35 | 36 | 37 | 40 | 41 | 58 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | NS | L | L | L | L | L | NS | NS | | L | L | L | L | L | L | L | L |
| 4 | | L | L | L | L | L | NS | NS | | L | L | L | L | L | L | L | L |
| 7 | | | NS | NS | NS | NS | NS | NS | | NS | NS | NS | NS | NS | NS | NS | NS |
| 8 | | | | NS | NS | NS | NS | H | | NS | NS | NS | NS | NS | NS | NS | NS |
| 88 | | | | | NS | NS | NS | NS | | NS | NS | NS | NS | NS | NS | NS | L |
| 13 | | | | | | NS | NS | NS | | NS | NS | NS | NS | NS | NS | NS | NS |
| 14 | | | | | | | NS | NS | | NS | NS | NS | NS | NS | NS | NS | L |
| 17 | | | | | | | | NS | | NS | NS | NS | NS | NS | NS | NS | L |
| 18 | | | | | | | | | | NS | NS | NS | NS | NS | NS | NS | L |
| 27 | | | | | | | | | | | NS | NS | NS | NS | NS | NS | L |
| 28 | | | | | | | | | | | | NS | NS | NS | NS | NS | L |
| 35 | | | | | | | | | | | | | NS | NS | NS | NS | NS |
| 36 | | | | | | | | | | | | | | NS | NS | NS | NS |
| 37 | | | | | | | | | | | | | | | NS | NS | L |
| 40 | | | | | | | | | | | | | | | | NS | NS |
| 41 | | | | | | | | | | | | | | | | | L |

Bartlett's Test -- Not Significant on (M12) or (M23)
F-Test -- Significant for (M12) and for (M23)

Legend: "H" indicates class on vertical axis scored significantly higher than comparison class listed on horizontal axis. "L" indicates class on vertical axis scored significantly lower than comparison class listed on horizontal axis. "NS" indicates that class was not significantly different than class listed on horizontal axis.

## Table 11 SUMMARY OF ANALYSIS OF VARIANCE RESULTS FOR ELECTRICITY PRE-TEST (E12) AND POST-TEST (E23) FOR GRADE 6 PUPILS

Comparison List of Classes

Main List of Classes

| (E12) | 4 | 7 | 8 | 13 | 14 | 17 | 18 | 22 | 27 | 28 | 35 | 36 | 37 | 40 | 41 | 58 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | NS | NS | NS | NS | NS | NS | NS |  | NS | NS | L | NS | NS | NS | NS | L |
| 4 |  | NS | NS | NS | NS | NS | NS |  | NS | NS | L | NS | NS | L | NS | L |
| 7 |  |  | L | L | L | NS | NS |  | NS | L | L | L | L | L | NS | L |
| 8 |  |  |  | NS | NS | NS | NS |  | NS | NS | NS | NS | NS | NS | NS | L |
| 13 |  |  |  |  | NS | NS | NS |  | NS | NS | NS | NS | NS | NS | NS | L |
| 14 |  |  |  |  |  | NS | NS |  | NS | NS | NS | NS | NS | NS | NS | L |
| 17 |  |  |  |  |  |  | NS |  | NS | NS | L | NS | NS | L | NS | L |
| 18 |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS | NS | NS | L |
| 27 |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS | NS | L |
| 28 |  |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS | L |
| 35 |  |  |  |  |  |  |  |  |  |  |  | NS | NS | NS | H | NS |
| 36 |  |  |  |  |  |  |  |  |  |  |  |  | NS | NS | NS | L |
| 37 |  |  |  |  |  |  |  |  |  |  |  |  |  | NS | NS | L |
| 40 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | H | NS |
| 41 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | L |

Main List of Classes

| (E23) | 4 | 7 | 8 | 13 | 14 | 17 | 18 | 22 | 27 | 28 | 35 | 36 | 37 | 40 | 41 | 58 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | NS | L | NS | L | NS | L | L | NS | L | NS | L | L | L | L | NS | L |
| 4 |  | L | NS | L | NS | L | L | NS | L | NS | L | L | L | L | NS | L |
| 7 |  |  | NS | NS | NS | NS | NS | H | NS | NS | NS | NS | NS | NS | NS | NS |
| 8 |  |  |  | NS | NS | NS | NS | H | NS | NS | NS | NS | NS | NS | NS | NS |
| 13 |  |  |  |  | NS | NS | NS | H | NS | NS | NS | NS | NS | NS | NS | NS |
| 14 |  |  |  |  |  | NS | NS | H | NS | NS | NS | NS | L | NS | NS | NS |
| 17 |  |  |  |  |  |  | NS | H | NS | NS | NS | NS | NS | NS | NS | NS |
| 18 |  |  |  |  |  |  |  | H | NS | NS | NS | NS | NS | NS | NS | NS |
| 22 |  |  |  |  |  |  |  |  | L | L | L | L | L | L | L | L |
| 27 |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS | NS | NS |
| 28 |  |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS | NS |
| 35 |  |  |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS |
| 36 |  |  |  |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS |
| 37 |  |  |  |  |  |  |  |  |  |  |  |  |  | NS | H | NS |
| 40 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | NS | NS |
| 41 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | NS |

Bartlett's Test -- Not Significant for (E12), Significant for (E23)
F-Test -- Significant for (E12) and for (E23)

Legend: "H" indicates class on vertical axis scored significantly higher than comparison class listed on horizontal axis. "L" indicates class on vertical axis scored significantly lower than comparison class listed on horizontal axis. "NS" indicates that class was not significantly different than class listed on horizontal axis.

## Table 12 SUMMARY OF ANALYSIS OF VARIANCE RESULTS FOR HEAT PRE-TEST (H12) AND POST-TEST (H23) FOR GRADE 6 PUPILS

Comparison List of Classes

MAIN LIST OF CLASSES

| (H12) | 4 | 7 | 8 | 13 | 14 | 17 | 18 | 27 | 28 | 35 | 36 | 37 | 40 | 41 | 58 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | NS | NS | L | L | L | L | L | L | L | L | L | L | L | L | L |
| 4 |  | NS | L | L | L | L | L | L | L | L | L | L | L | L | L |
| 7 |  |  | L | L | L | NS | NS | NS | NS | L | L | L | L | NS | L |
| 8 |  |  |  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 13 |  |  |  |  | NS | H | H | H | H | NS | NS | NS | NS | H | NS |
| 14 |  |  |  |  |  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 17 |  |  |  |  |  |  | NS | NS | NS | L | L | L | L | NS | L |
| 18 |  |  |  |  |  |  |  | NS | NS | L | NS | L | L | NS | L |
| 27 |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS | NS | NS |
| 28 |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS | NS |
| 35 |  |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS |
| 36 |  |  |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS |
| 37 |  |  |  |  |  |  |  |  |  |  |  |  | NS | H | NS |
| 40 |  |  |  |  |  |  |  |  |  |  |  |  |  | H | NS |
| 41 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | L |

MAIN LIST OF CLASSES

| (H23) | 4 | 7 | 8 | 13 | 14 | 17 | 18 | 27 | 28 | 35 | 36 | 37 | 40 | 41 | 58 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 |  |  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 8 |  |  |  | NS | NS | H | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 13 |  |  |  |  | NS | H | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 14 |  |  |  |  |  | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| 17 |  |  |  |  |  |  | NS | L | NS | L | NS | NS | L | NS | L |
| 18 |  |  |  |  |  |  |  | NS | NS | NS | NS | NS | NS | NS | NS |
| 27 |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS | NS | NS |
| 28 |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS | NS |
| 35 |  |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS | NS |
| 36 |  |  |  |  |  |  |  |  |  |  |  | NS | NS | NS | NS |
| 37 |  |  |  |  |  |  |  |  |  |  |  |  | NS | NS | NS |
| 40 |  |  |  |  |  |  |  |  |  |  |  |  |  | NS | NS |
| 41 |  |  |  |  |  |  |  |  |  |  |  |  |  |  | NS |

Bartlett's Test -- Not Significant for (H12) or for (H23)
F-Test -- Significant for (H12) and for (H23)

Legend; "H" indicates class on vertical axis scored significantly higher than comparison class listed on horizontal axis. "L" indicates class on vertical axis scored significantly lower than comparison class listed on horizontal axis. "NS" indicates that class was not significantly different than class listed on horizontal axis.

be noted that the pupils in class #58 were also significantly higher in their scores than some of the pupils in the other sixth grade classes. In particular, class #58 was significantly higher than classes (#88,14,18,17,27,37,41).

Class #3 and #4 had entered instruction with significantly lower scores than the other sixth grade classes and they concluded instruction with significantly lower scores than the other classes. These pupils were in low socio-economic communities and this result was not surprising. Class #17 had entered instruction with significantly lower scores than the other classes, but improved to the state where it was not significantly lower than the other sixth grade classes on the (M23) test. Classes (#8,58) entered instruction with significantly higher scores on the initial test and concluded instruction with significantly higher scores on the final test.

3. Electricity Pre-Test (E12) - The Bartlett's Test indicated that there were no significant differences among the variances of the classes in this group. An F Test and the appropriate T Tests revealed that significant differences did exist between low-scoring classes (#3,4,7,17,41) as compared to the high-scoring classes (#13,14,28,35,36,37,40,58).

Class #58 made initial scores of the (E12) test which placed it significantly higher than all of the other grade six classes except classes (#35,40). This suggested that class #58 may have studied electricity at a previous time, but no information was collected to test this conjecture. On the other hand, only 14 of the 29 pupils were tested and this was approximately one half of the entire class; which might also account for the extremely high scores made by a small group of students.

Graphical analysis indicated that classes #36 and #41 had positively skewed distributions on the (E12) test, but this distribution of scores within the classes did not cause their variances or mean scores to be significantly lower than the other sixth grade classes.

4. Electricity Post-Test (E23) - The Bartlett's Test indicated that there were significant differences among the sixth grade classes on the (E23) test. The F Tests were conducted between pairs of classes and revealed that these differences were attributalbe to low-scoring classes (#3,4,22) versus the high-scoring classes (#7,8,13,14,17,18,27,28,35,36,37,40,41,58).

Classes #3 and #4 had entered instruction for electricity with significantly lower scores on the initial test and remained significantly lower than the other classes as indicated by their scores on the (E23) test. It is interesting to note that the same Detroit teacher taught classes #3 and #4. This teacher had an excellent background of undergraduate science work. However, these children came from low-socio-economic communities and seemed to follow the same pattern of low achievement on tests.

It is also interesting to note that class #41 was taught by the same science teacher in a suburban school who taught class #40 in a self-contained setting. The pupils in class #40 scored significantly higher than the pupils in classes #3 and #4 on the (E23) test. The pupils in class #40 scored somewhat higher than pupils in class #41, but this was not statistically significant.

5. Heat Pre-Test (H12) - The Bartlett's Test did not reveal substantial differences among the variances of classes in the sixth grade for this test. An F Test indicated that there were significant differences among the classes. Subsequent T Tests indicated that the differences could be attributed to low-scoring classes (#3,4) which scored significantly lower than all other sixth grade classes on the (H12) test except class #7. The T Tests also indicated that classes (#7,17,18,27,28,41) scored significantly lower than classes (#8,13,14,35,36,37,40,58).

6. Heat Post-Test (H23) - The Bartlett's Test indicated that there was not a significant difference among the sixth grade classes on the (H23) test. An F Test indicated that there was a significant difference among these classes, and T Tests revealed that the differences could be attributed to low-scoring class (#17) as compared to the high-scoring classes (#8,13,27,37,40,58). Classes #3 and #4 were excluded from the analysis of the (H23) test in the sixth grade sample because there were only 7 and 8 cases remaining in those two groups.

D. Sex Differences in Achievement. Table 13 provides a summary statement of sex difference in achievement on each of the unit tests. It indicates significant differences existed in achievement for simple machines (M12,M23), electricity (E12,E23), for all pupils in each of the eight schools.

There was a sex difference in the achievement on the Machines Pre-Test (M12) which favored the boys in Detroit schools #1, 2, and 3. However, there was no significant difference in the achievement of boys and girls in any of the Detroit schools on the Machines Post-Test (M23).

Table 13 SUMMARY OF SIGNIFICANT DIFFERENCES BETWEEN BOYS AND GIRLS ON UNIT ACHIEVEMENT TESTS

| Schools | Unit Achievement Tests | | | | | |
|---|---|---|---|---|---|---|
| | Machines | | Electricity | | Heat | |
| | M12 | M23 | E12 | E23 | H12 | H23 |
| Detroit #1 | M | NS | M | NS | NS | NS |
| Detroit #2 | M | NS | M | NS | NS | NS |
| Detroit #3 | M | NS | NS | NS | NS | NS |
| Detroit #4 | NS | NS | NS | NS | NS | NS |
| Detroit #5 | NS | NS | M | NS | NS | NS |
| Suburban #6 | NS | M | M | M | NS | NS |
| Suburban #7 | NS | NS | NS | NS | NS | NS |
| Suburban #8 | NS | NS | NS | NS | NS | NS |

Legend: NS...No significant differences in scores made by boys or girls
F...Females scored significantly higher on the test and in the school
M...Males scored significantly higher
Significant differences identified with t-test at 1% level of confidence.

The suburban schools did not indicate significant differences in the achievement of boys and girls on the Machines Pre-Test (M12), but the boys in school #6 did achieve significantly higher scores on the Machines Post-Test (M23). Otherwise, there were no differences in achievement of boys and girls on the (M23) test in any of the other two suburban schools.

On the Electricity Pre-Test (E12), there were sex differences which favored boys making higher scores in schools #1, 2, 5, and 6. However, these differences in achievement of boys over girls disappeared on the Electricity Post-Test (E23), except for the continued success of boys over girls in suburban school #6.

Table 13 shows that for the Heat Pre-Test (H12) and the Post-Test (H23), there were no significant differences in the achievement of boys or girls in any of the schools.

## 2. Graphical Analysis of Data

Graphical analysis of the data was used to identify changes in the distributions of pupils' scores between the pre-test and the post-test for each unit test and for each of the grade groups. The details of this analysis have been described in the tables in Appendix H. Table 14 shows a summary of the changes in distribution of the grade groups for different units of instruction. It is apparent from the table that large numbers of classes in all three grade groups tended to have a normal distribution before instruction and a normal distribution after instruction. This was consistent for the units of instruction on machines, electrical energy, and heat energy. The only exception occurred in the case of the electricity unit in which there appeared to be changes from a normal distribution on the pre-test to log-normal or skewed distributions on the post-test. None of the classes indicated a negatively skewed distribution on any of the unit achievement tests at any of the grade levels.

Skewed distributions occurred in low, middle, and high socio-economic groups. They have occurred in situations where instruction was directed by non-specialists in science and in classes taught by science specialists. There does not seem to be a consistent pattern in the occurrence of positively skewed distributions, although some classes tended to have skewed distribution for one unit achievement test and have normal or log-normal distribution for other unit achievement tests.

There were 19 occasions when a skewed distribution occurred. There were 62 occasions when a class had a normal distribution when instruction began and had a normal distribution when instruction ended. There were 76 occasions when the terminal distribution was normal or log-normal. In summary, it should be repeated that there was a general tendency toward normal distribution of scores within classes, although there might be variations in the distribution before instruction or after instruction.

The graphs indicated clearly that low socio-economic groups scored significantly lower than middle or high socio-economic groups. This occurred at grade 4, 5, and 6. The evidence was only applicable to classes that were taught by the special science teachers. Since the suburban classes did not include a sample of pupils from a low socio-economic community, a direct comparison including suburban schools was not possible.

When the distribution of scores within a class was determined to be normal, for the pre-test and the post-test, this

Table 14 CHANGES IN DISTRIBUTION OF CLASSES' SCORES FROM PRE-TEST TO POST-TEST

| Pattern of Distribution | Machines (M12 to M23) | | Electricity (E12 to E23) | | Heat (H12 to H23) | |
|---|---|---|---|---|---|---|
| | Grade | No. of Classes | Grade | No. of Classes | Grade | No. of Classes |
| N-N | 4 | 5 | 4 | 4 | 4 | 5 |
| | 5 | 6 | 5 | 1 | 5 | 8 |
| | 6 | 14 | 6 | 7 | 6 | 11 |
| N-LN | 4 | 0 | 4 | 1 | 4 | 0 |
| | 5 | 3 | 5 | 4 | 5 | 0 |
| | 6 | 0 | 6 | 1 | 6 | 0 |
| N-S | 4 | 0 | 4 | 1 | 4 | 0 |
| | 5 | 2 | 5 | 2 | 5 | 1 |
| | 6 | 0 | 6 | 4 | 6 | 0 |
| LN-N | 4 | 1 | 4 | 1 | 4 | 0 |
| | 5 | 3 | 5 | 0 | 5 | 0 |
| | 6 | 2 | 6 | 1 | 6 | 1 |
| LN-LN | 4 | 0 | 4 | 0 | 4 | 1 |
| | 5 | 0 | 5 | 0 | 5 | 0 |
| | 6 | 1 | 6 | 0 | 6 | 0 |
| LN-S | 4 | 0 | 4 | 0 | 4 | 0 |
| | 5 | 0 | 5 | 0 | 5 | 3 |
| | 6 | 0 | 6 | 1 | 6 | 0 |
| S-N | 4 | 0 | 4 | 0 | 4 | 0 |
| | 5 | 0 | 5 | 1 | 5 | 0 |
| | 6 | 0 | 6 | 1 | 6 | 0 |
| S-LN | 4 | 0 | 4 | 0 | 4 | 0 |
| | 5 | 0 | 5 | 2 | 5 | 0 |
| | 6 | 0 | 6 | 0 | 6 | 0 |
| S-S | 4 | 0 | 4 | 0 | 4 | 1 |
| | 5 | 0 | 5 | 1 | 5 | 0 |
| | 6 | 1 | 6 | 0 | 6 | 0 |

provided an opportunity to compare growth or improvement made by pupils in the Detroit schools and those in the suburban schools. There seemed to be as many occasions when there were significant differences between classes in the same grade group taught by the same teacher, as between classes taught by the science specialist in Detroit and other classes taught by teachers in self-contained classes in the suburbs.

The six hypothetical eases shown in Appendix H enabled the researcher to make comparisons between increases in the median scores and increases in the average rate of growth within a given classroom.

Table 15 indicates frequencies of occurrence for each of the hypothetical cases which had a normal distribution before instruction and a normal distribution after instruction had ended. Of the 62 instances of the pattern (N-N), the largest number (35) occurred as instances of hypothetical case #6. This indicated that there was a significant gain in the median scores following instruction and there was also a substantial increase in the slope or average rate of change. In substance, this implied that while the total group made improvement, the upper portion of the class made substantially larger improvement than the lower portion of the class, which made little or no improvement.

The second largest number (18) of instances of (N-N) pattern fell into hypothetical case #1. This indicated that the entire group made significant gains on the post-test and that these equivalent improvements were made by pupils at all levels in the class.

Another significant observation about the information in Table 15 was that there were no instances of hypothetical case #4 or #5. This clearly indicated that the instruction presented in these units did not enable pupils who were patently low on the initial test to make greater improvements at any time than the pupils who were above the median on the initial test.

Five instances of the (N-N) pattern were classified as representative of hypothetical case #2, which indicated no substantial improvement in either the median score or in the slope of the curves after instruction. It is noteworthy that four of these five instances occurred in classes of pupils from low socio-economic communities.

Table 15 FREQUENCY OF HYPOTHETICAL CASES FOR CLASS DISTRIBUTIONS HAVING (N-N) PATTERN FOR UNIT ACHIEVEMENT TESTS

| (N-N) Hypothet. Cases | Gr. Gps. | Mach. Test | Elect. Test | Heat Test | Totals |
|---|---|---|---|---|---|
| #6 | 4 | 4 | 2 | 2 | 8 |
| | 5 | 4 | 1 | 4 | 9 |
| | 6 | 10 | 4 | 4 | 18 |
| #5 | 4 | 0 | 0 | 0 | 0 |
| | 5 | 0 | 0 | 0 | 0 |
| | 6 | 0 | 0 | 0 | 0 |
| #4 | 4 | 0 | 0 | 0 | 0 |
| | 5 | 0 | 0 | 0 | 0 |
| | 6 | 0 | 0 | 0 | 0 |
| #3 | 4 | 1 | 0 | 0 | 1 |
| | 5 | 0 | 0 | 1 | 1 |
| | 6 | 1 | 1 | 0 | 2 |
| #2 | 4 | 0 | 1 | 1 | 2 |
| | 5 | 1 | 0 | 0 | 1 |
| | 6 | 1 | 1 | 0 | 2 |
| #1 | 4 | 1 | 1 | 2 | 4 |
| | 5 | 1 | 0 | 3 | 4 |
| | 6 | 2 | 1 | 7 | 10 |

Total 62

## 3. Gain Scores

For each of the unit achievement tests, a comparison was made to discover the gains in raw scores which were made between the initial pre-test (M12, E12, H12) and its corresponding post-test after instruction (M23, E23, H23). This provided a set of raw scores which indicated the gains in correct responses which might be attributed to instruction in the particular unit.

Figure 6 shows three curves which illustrate the gain scores made by fourth grade pupils on the three unit achievement tests. Figures 7,8 illustrate gain scores made by pupils in the fifth grade and by pupils in the sixth grade.

For pupils in grade four the range of gain scores extended from -4 points to +15 points. Figure 6 indicated that approximately 6 pupils made scores below -2 and at least 7 pupils made scores above +11. This corresponded to a change for the total test which ranged from 8% loss to gain of approximately 30% for some of the fourth grade pupils. The mean gain was 3.5 correct responses which corresponds to about 7% gain.

These changes refer to gains made for the machines unit test. Similar gains are noted by the solid line graph and the dash line graph for gains made by fourth grade pupils as a result of instruction in electricity and in heat energy. These distributions of gain scores are very similar for all three groups and approximate a normal distribution.

The bar graph in Figure 7 shows a distribution of gain scores for fifth grade pupils for the machines unit. It indicates a range of scores from a -7 points to a +22 points. This corresponds to a range of 14% loss to a gain of 44%. The mean gain score for the fifth grade group was 4.3 correct responses which corresponds to about 8.6% gain.

The other line graphs show the distribution of gain scores of fifth grade pupils for electricity and for heat energy. The three distributions are very similar and approximate a normal distribution. The mean gain score for electrical energy for fifth grade pupils was 3.8 and the mean gain score for fifth grade pupils on the heat energy unit was 2.8. These figures correspond to 7.6% and 5.6% gains respectively.

The bar graph in Figure 8 shows the distribution of gain scores for sixth grade pupils for machines, electricity, and heat energy. The range of scores for the machines unit extended from -7 to +19, which corresponds to a range extending from 14% loss to 38% gain.

Figure 6 DISTRIBUTION OF GAIN SCORES OF FOURTH GRADE PUPILS FOR MACHINES (M23-M12), ELECTRICITY (E23-E12), HEAT (H23-H12)

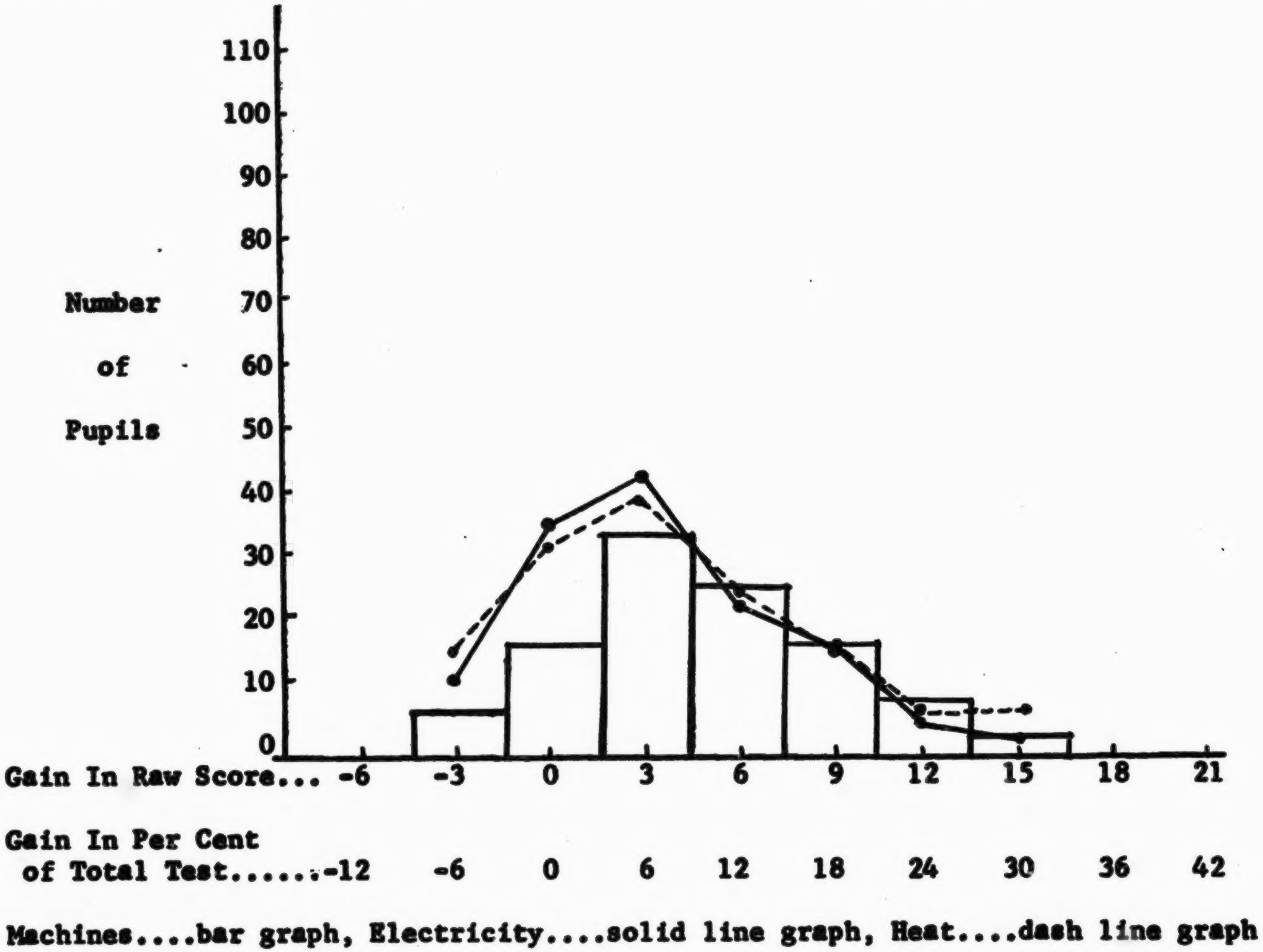


Figure 7 DISTRIBUTION OF GAIN SCORES OF FIFTH GRADE PUPILS FOR MACHINES (M23-M12), ELECTRICITY (E23-E12), HEAT (H23-H12)

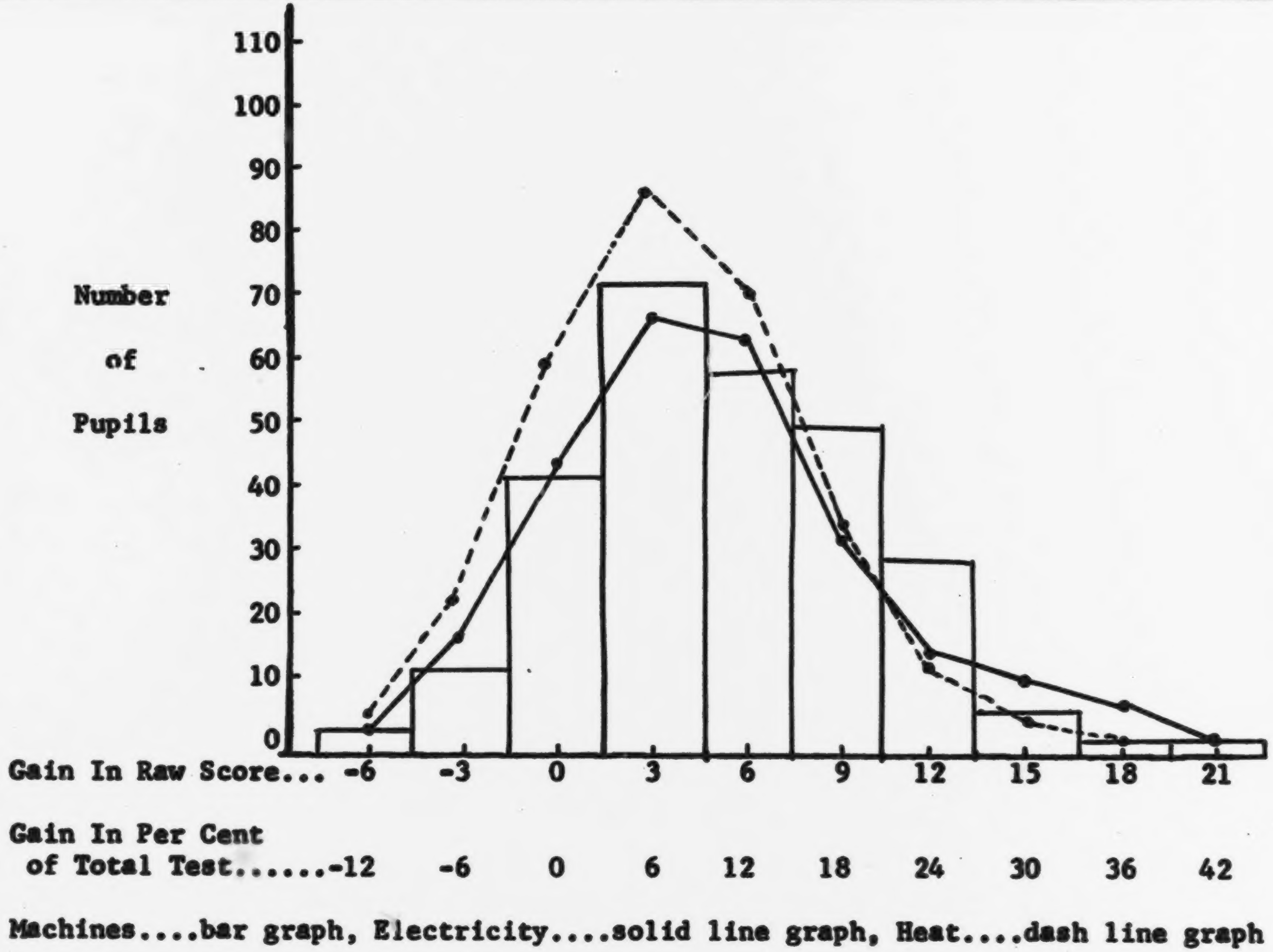
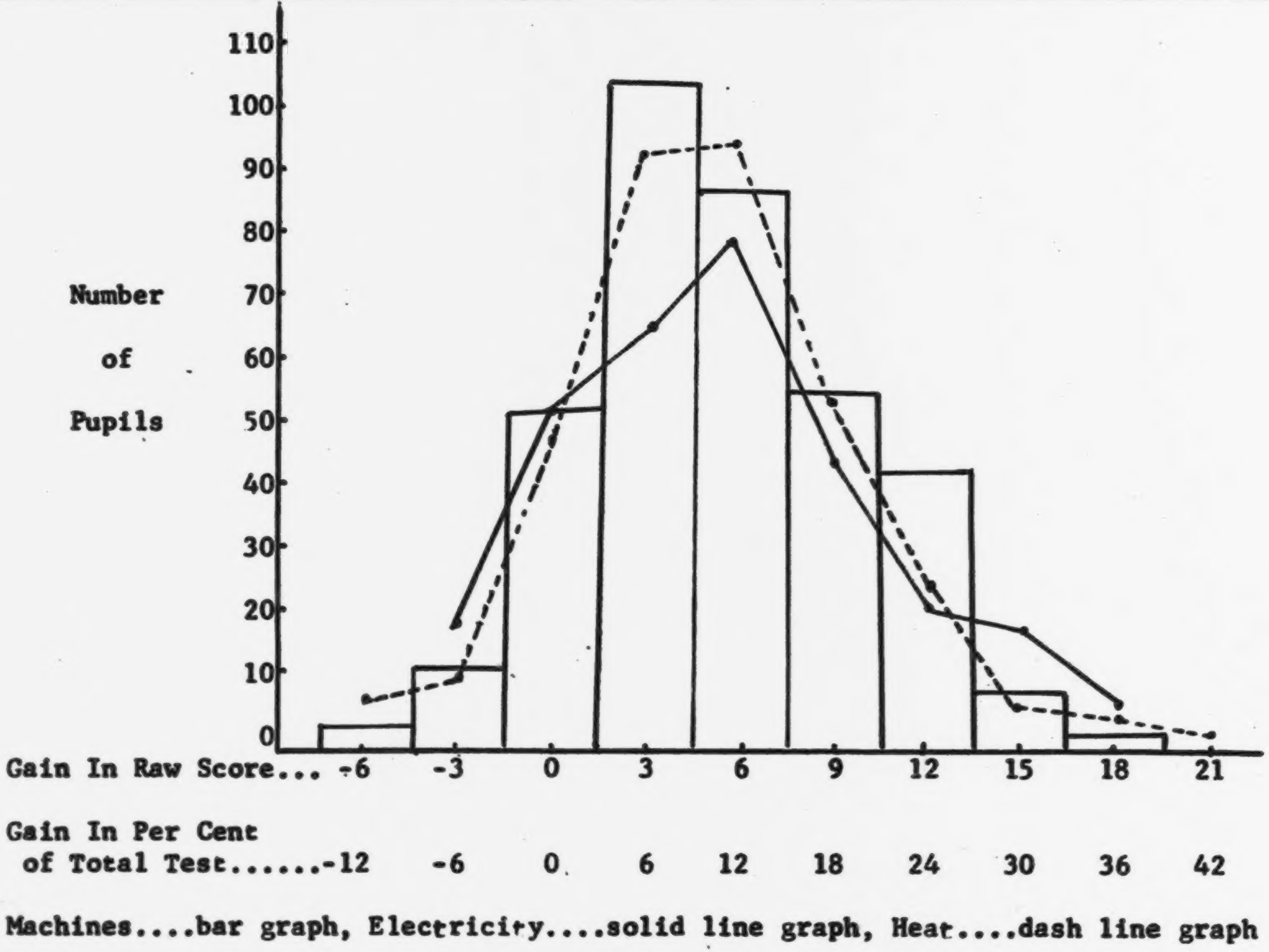


Figure 8 DISTRIBUTION OF GAIN SCORES OF SIXTH GRADE PUPILS FOR MACHINES (M23-M12), ELECTRICITY (E23-E12), HEAT (H23-H12)



The solid line and the dash line show distributions of gain scores of sixth grade pupils for the electricity test and the heat test. The three distributions are very similar, and approximate a normal distribution. For the electricity test, the mean gain was 4.3 or 8.6%, and the mean score gain for heat energy was 4.1 or 8.2% gain.

## 4. Standardized Tests of Achievement

### A Analysis of Variance Results

1. Grade 4 - For the standardized reading comprehension test, the Bartlett's Test indicated that there was a significant difference among the variances of the fourth grade classes. Classes (#9,38) had substantially higher variances than did classes (#20,24,23). The mean score of class #20 was lowest in the group. Corresponding tables may be found in Appendix H.

The Bartlett's Test indicated a significant difference in the scores made on the standardized science achievement test. Class #9 was significantly high and classes (#24,23,20) were significantly low. The mean score of class #20 was lowest of the fourth grade classes and class #9 made the highest score in science achievement.

The Bartlett's Test indicated no significant difference in the verbal intelligence test scores for the fourth grade pupils. An F-test indicated that there was a significant difference, and subsequent T Tests identified class #20 as scoring lowest and classes (#38,9) scored high.

2. Grade 5 - For the standardized reading comprehension test, the Bartlett's Test indicated a significant difference existed among the variances. Classes (#1,21) had small variances and classes (#39,15,16) had large variances. Interestingly, class #2 was not significantly different in either the mean scores or the variances on the reading comprehension. Low mean scores were made by classes (#21,1) and high mean scores were made by classes (#33,34,39,6).

The Bartlett's Test indicated that there were significant differences on the standardized science achievement test. Class #1 had small variance in comparison to the classes (#39,16). Low mean scores on this test were made by classes (#21,1). High mean scores were made by (#15,5,32,34). Class #2 did not have a significantly lower mean score or a significantly different variance than the other grade five classes.

The Bartlett's Test indicated that there were no significant differences in the verbal intelligence scores made by grade 5 pupils. An F-test indicated that there were significant differences. Subsequent T Tests indicated that the differences could be attributed to low mean scores made by classes #1 and #21 as compared with classes (#32,5,33,34). Class #2 was not significantly different than any of the other grade five classes with respect to mean score or variance within that class.

3. Grade 6 - The Bartlett's Test indicated that there was a significant difference in the sixth grade pupils' reading comprehension scores. Classes (#3,4) scored significantly lower than classes (#18,37). Mean scores of classes (#3,4,22) were substantially below those of mean scores for classes (#58, 40,41,8,14,18).

For the standardized science achievement test, the Bartlett's Test indicated that a significant difference existed among the low-scoring classes (#22,3,4) and high-scoring classes (#58,18, 13). Low mean scores were made by classes (#3,4,22) as contrasted with high mean scores made by (#58,8,28,35,37,7,14).

The Bartlett's Test indicated that there was not a significant difference in the variance of the sixth grade pupils on the standardized test of verbal intelligence. An F-test indicated that there was a significant difference. T Tests revealed significant differences between low-scoring classes (#3,4,22) and high-scoring classes (#35,36,40,7).

### B. Correlation Coefficients Between Test Variables

Table 16indicates the correlations among the unit achievement tests for pupils in grades 4,5, and 6. If one considers the fourth grade matrix, it is apparent that there is a substantial correlation ($r = .70$ to $r = .86$) between the pre-test and the post-test for machines (M12 with M23), electricity (E12 with E23), and heat (H12 with H23). In come cases, the correlation from one unit test to another increased to a high of $r = .77$ in the case of the correlation between the (E23) test and the (H23). On the other hand, the correlation dropped to $r = .55$ for the correlations between the (M12) test and the (H23) test.

Inspection of the matrices for the correlations among the unit tests for the fifth grade pupils and for the sixth grade pupils indicates that the magnitudes of those correlation coefficients are similar to the values computed for the fourth grade samples.

Table 16 CORRELATION MATRIX FOR UNIT ACHIEVEMENT TESTS SCORED BY DOUBLE PRECISION FOR FOURTH GRADE, FIFTH GRADE, SIXTH GRADE PUPILS*

| Test Variable | Test Variable | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fourth Grade | M23 | E12 | E23 | H12 | H23 | M23 | E12 | E23 | H12 | H23 | M23 | E12 | E23 | H12 | H23 |
| M12 | 75 | 60 | 62 | 58 | 55 | | | | | | | | | | |
| M23 | | 70 | 77 | 72 | 70 | | | | | | | | | | |
| E12 | | | 74 | 61 | 64 | | | | | | | | | | |
| E23 | | | | 75 | 77 | | | | | | | | | | |
| H12 | | | | | 86 | | | | | | | | | | |
| Fifth Grade | | | | | | | | | | | | | | | |
| M12 | | | | | | 73 | 52 | 51 | 55 | 54 | | | | | |
| M23 | | | | | | | 62 | 71 | 71 | 73 | | | | | |
| E12 | | | | | | | | 78 | 68 | 62 | | | | | |
| E23 | | | | | | | | | 71 | 73 | | | | | |
| H12 | | | | | | | | | | 83 | | | | | |
| Sixth Grade | | | | | | | | | | | | | | | |
| M12 | | | | | | | | | | | 78 | 56 | 54 | 52 | 55 |
| M23 | | | | | | | | | | | | 63 | 71 | 69 | 70 |
| E12 | | | | | | | | | | | | | 78 | 68 | 59 |
| E23 | | | | | | | | | | | | | | 74 | 74 |
| H12 | | | | | | | | | | | | | | | 80 |

*All correlation coefficients are 2-digit, positive numerals, unless specified otherwise. A decimal point is understood to precede each coefficient.

Table 17 CORRELATION MATRIX FOR STANDARDIZED TESTS OF READING, SCIENCE, VERBAL INTELLIGENCE WITH UNIT ACHIEVEMENT TESTS FOR PUPILS IN GRADES FOUR, FIVE AND SIX

| Test Variable | Read. | Sci. | I.Q. | Read. | Sci. | I.Q. | Read. | Sci. | I.Q. |
|---|---|---|---|---|---|---|---|---|---|
| **Fourth Grade** | | | | | | | | | |
| M12 | 58 | 61 | 46 | | | | | | |
| M23 | 68 | 66 | 63 | | | | | | |
| E12 | 51 | 53 | 34 | | | | | | |
| E23 | 61 | 64 | 54 | | | | | | |
| H12 | 55 | 60 | 56 | | | | | | |
| H23 | 56 | 64 | 58 | | | | | | |
| Read. | | 78 | 65 | | | | | | |
| Sci. | | | 66 | | | | | | |
| **Fifth Grade** | | | | | | | | | |
| M12 | | | | 51 | 58 | 53 | | | |
| M23 | | | | 51 | 57 | 63 | | | |
| E12 | | | | 34 | 52 | 47 | | | |
| E23 | | | | 46 | 58 | 52 | | | |
| H12 | | | | 40 | 59 | 50 | | | |
| H23 | | | | 42 | 57 | 51 | | | |
| Read. | | | | | 71 | 75 | | | |
| Sci. | | | | | | 74 | | | |
| **Sixth Grade** | | | | | | | | | |
| M12 | | | | | | | 52 | 56 | 50 |
| M23 | | | | | | | 58 | 66 | 59 |
| E12 | | | | | | | 43 | 51 | 39 |
| E23 | | | | | | | 55 | 64 | 52 |
| H12 | | | | | | | 50 | 56 | 49 |
| H23 | | | | | | | 57 | 61 | 60 |
| Read. | | | | | | | | 72 | 69 |
| Sci. | | | | | | | | | 72 |

Table 17 indicates the correlations among the unit achievement tests and standardized tests for reading comprehension, science background, and verbal intelligence. For the fourth grade sample, achievement tests are of the order of (r = .51 to r = .68). The correlations of the unit with the standard science achievement test extends from (r = .53 to r = .78). Correlation coefficients of unit achievement tests and verbal intelligence scores of the fourth grade class ranged between (r = .34 and r = .66)

For the fifth grade sample, the correlation between the unit achievement tests and reading comprehension extended from(r = .34 to r = .51). The correlations for science achievement extended from (r = .52 to r = .59). The correlations for verbal intelligence reanged from (r = .47 to r = .63).

For sixth grade pupils, the correlations between unit achievement tests and the standardized tests for reading comprehension, science, and verbal intelligence had the respective ranges of (r = .43 to r = .58), (r = .51 to r = .66), and (r = .39 to r = .62).

## 5. Item Analysis of Unit Test Data

A. Pupils' Correct Responses to Test Items. In the following remarks, the results of pupils' responses to the various items on the unit achievement tests will be summarized for simple machines, electrical energy, and for heat energy. Since the results were similar for tests for all three units, it was considered to be unnecessary to repeat the same detailed report of results for each of the three sets of data separately. The discussion deals with differences in success achieved by pupils in grades 4, 5, and 6. Estimates of pupils' probable success in understanding the generalizations for simple machines, electrical energy, and heat energy are shown in Appendices A, B, and C.

An examination of the correct response patterns for each of the grade levels indicated that one characteristic pattern was for pupils at each of the grade levels to achieve the same level of success on a given test item on the pre-test and on the post-test. For example, the test item generalization for item #1 on the machines test may be stated:

"An automobile has mechanical energy for use."

Inspection of Appendix A indicates that for each of the three grade groups about 54% of the pupils responded correctly to this test item before instruction (M12). There was no appreciable change in the proportions scoring correctly on the (M23) test after instruction.

The lack of change may be verified by referring to the confidence belts in Appendix D. The number of pupils in the fifth grade sample was approximately 300 pupils for the machines post-test (M23). The per cent correct responses to the (M23) test by fifth grade pupils was 56%. By referring to Figure 9 , the appropriate confidence curve would be for samples between 200 and 400 subjects, the proportion under consideration would be 56%, which is located on the horizontal axis at the top of Figure 9. The curves in that figure indicate that one may be 90% confident that the true proportion lies between 62% and 50%. Since the per cent correct responses of fourth grade groups and the per cent correct responses of the sixth grade groups are 54% and 53%, respectively, it is apparent that there were no significant differences among the three grade groups in responding to this test item.

For each unit achievement test, there were several test items which revealed similar proportions for all three grade groups before and after instruction. Occasionally, this occurred when the proportions of successful responses were relatively high as in the case of item #1 and #4 on the machines test. However, it was generally the case that test items were about the same level of difficulty for all three grade groups when the proportion of correct responses was low for each grade group before and after instruction. This occurred for items #2 and #6 for the machines test, for items #1, 4, 9, and 19 on the electricity test, and for heat test items #9, 11, 17, 25, and 48.

A second set of test items showed a somewhat different pattern in that they revealed a pronounced increase in the per cent of correct responses from grade 4 to grade 5 to grade 6. For example, the test item generalization for item #17 on the machines test may be stated:

"If it is a shovel or a crowbar or a hammer, then it may be used as a lever."

For this item there was a pronounced increase in the per cent of correct responses on the machines post-test (M23). This changed from 25% to 34% to 48% for the respective grade groups of 4, 5, and 6. There was a similar but less pronounced increase for the same grade groups on the machines pre-test (M12) for that same item and those same grade groups.

If one looks at Figure 9 with the 34% correct responses of grade 5 and the sample size of 296 pupils, the boundaries for the true proportions for that grade group are approximately 29% and 40%. Therefore, one can asert that there was a modest but significant difference in the proportion of correct responses made by fourth grade pupils and fifth grade pupils as well as a significant difference in the proportion of correct responses made by fifth grade pupils and by sixth grade pupils to this particular test item on the machines test (M23).

One may also use the same confidence belts to determine whether or not the change in per cent correct responses was a significant change for grade 5 pupils. Since only 12% of grade 5 pupils responded correctly to item #17 on the Machines Pre-Test (M12), this is clearly outside the limits of the 29% to 40% band. Therefore, a larger and statistically significant proportion of fifth grade pupils did respond correctly to item #17 and one may infer that the increased understanding was attributable to the instruction on the topic of simple machines.

Similar patterns were identified for the electricity test.

In particular, this occurred on the Electricity Pre-Test (E12) for items #38 and #39; it occurred on the Electricity Post-Test (E23) for items (#5,12,11,38). Only once did this pattern occur on the Heat Pre-Test (H12) and this was for item #34. It did occur on the Heat Post-Test (H23) for items (#13,16,35,37).

Another pattern which seemed to characterize the responses to the unit achievement tests was evident when there was only a modest difference between the proportion of correct responses for pupils in grade 5 and 6, while the proportion of correct responses made by fourth grade pupils to the same test item was significantly lower. For the Machines Pre-Test (M12), this was evident for test items (#3,4,21,22,37, and others). For the Machines Post-Test (M23), the same items often exhibited this pattern (#3,4,21,22,37); however, there were more items on the Machines Post-Test (M23) which reflected this pattern than there were on the Machines Pre-Test (M12). Specifically this was true for test items (#16,28,34,39, and others).

For the Heat Pre-Test (H12) and the Heat Post-Test (H23), there were several items which exhibited this pattern on both tests. For example, this was true of test items (#2,5,8,35, 50, and others). However there were some items on the Heat Post-Test (H23) which exhibited the pattern but the similar pattern was not on the Heat Pre-Test (H12). Specifically this referred to test items (#1,7, and others).

In contrast, there were only a few of the items on the Electricity Pre-Test (E12) and the Electricity Post-Test (E23) which exhibited this pattern for both tests. Specifically this occurred for items (#17,25,32). Very few of the Electricity Pre-Test (E12) items reflected this pattern. On the other hand, a large number of the Electricity Post-Test (E23) items did reflect this pattern. Specifically this applied to test items (#21,18,2,16,17,37,32,40, and others).

A fourth pattern which seemed to characterize the pupils' responses to the various unit achievement tests was evident in the increase in the per cent correct responses from the pre-test to the post-test. One variation of this pattern occurred when all three grade levels revealed significant increases in the per cent of correct responses. This was characteristic of machines test for items (#3,4,17,35,36, and others). For the electricity test, this was characteristic of items (#18,22,5, and others). For the heat test, this was characteristic of test items (#2,1, 13, and others).

A larger number of the test items on the unit achievement test revealed a variation of this pattern by having an increase in proportion of correct responses from the pre-test to the post-test at one grade level or at two different grade levels. It is important to note that this increase in per cent correct responses might occur at the fourth grade level and not at the fifth or sixth grade level. It might occur at the fifth grade level and not at the fourth or sixth grade levels. It might occur at the fifth and sixth grade levels and not at the fourth grade level. In other words, there was not a consistent, identifiable pattern in noting significant increases in per cent correct responses in this variation of pattern #4.

Specifically the increase of one or two grade levels occurred on the machines test for 15 items or more and this included test items (#7,8,16,21,24,26, and others). The increase at one or two grade levels for the electricity test occurred for 12 or more test items and this occurred for test items (#3,2,6,11,16, and others). The pattern for the heat test occurred for approximately 15 test items. Specifically, it occurred for test items (#3,5,6,4,10,36,37,26, and others).

B. Identification of Error Patterns. It is common for teachers to be concerned primarily with the total correct responses made by pupils to test items. A substantial increase in total correct responses from pre-test to post-test is often interpreted as a corresponding increase in understanding of the topic. However, the couputer makes it possible to consider the error response patterns which characterize groups of pupils as well as their correct response patterns. The tree diagram which is shown in Appendix G has indicated the large number of possible response paths which may characterize the network of responses to any multiple-choice test item.

A detailed analysis of error response patterns was beyond the available energies of the researcher or the available time and resources of this research project. Therefore, the researcher can only suggest to the reader some of his insights, gleaned from a cursory exploration of the error response patterns.

The following remarks have been restricted to the error patterns derived from pupils' responses to the Machines Pre-Test (M12) and the Machines Post-Test (M23). Therefore, it should be understood that these error responses were either made prior to instruction and reiterated directly after instruction, or they were asserted by the pupils directly after instruction and reiterated on the retention test administered three to five months after instruction had concluded.

Table 18 indicates the per cent correct responses of sixth grade pupils to each of the items on the (M12) test and the (M23) test. Inspection of these items leads to certain basic observations. The per cent correct responses to this test before instruction and after instruction ranged from a very low per cent of correct responses (4%,3%) to a very high per cent of correct responses (76%,73%).

It is interesting to note that when an item was answered correctly by 25% or more of the pupils, the per cent of error responses is substantially lower than when the per cent correct responses was less than 25%. For example, item #2 had only 3% correct responses on the (M12) test, and response #1 and #2 received 16% and 38% response frequencies respectively. In order to suggest what these error responses mean, the researcher has listed all of the student misunderstandings which may be inferred from their responses to the other options included in each test question. This list for the Machines Test is included in Appendix G .

In the case of item #2, the pupils' responses indicate that at least 16% of them believed that after a boy has used energy in a race, he still retains that energy. This occurred on the (M12) test and garnered (17%) on the (M23) test. Moreover, the second response indicates that the students believed than once a boy has used energy in running a race, the energy is entirely "used up". This was true of 38% on the (M12) test and 45% on the (M23) test. This is directly contradictory to the basic principle of conservation of energy, and it is apparent that this unit made no substantial improvement in helping youngsters to perceive the meaning of this major generalization.

If one were to undertake another science class with pupils in this sample, it seems that the teachers would wish to know that children do not consistently accept the conservation of energy principle.

It is also interesting to note that for the pre-test and the post-test, there were only about 57% and 70% of the youngsters who were consistent in their thinking before and after instruction. This leaves a substantial number of pupils in the sample who are uncertain or are vacillating in their thinking about this particular matter.

In the case of item #5, the test question attempted to determine

Table 18 COMPARISON OF CORRECT RESPONSES AND ERROR RESPONSES OF GRADE 6 PUPILS ON MACHINES PRE-TEST (M12) AND POST-TEST (M23)

| | (M12)Test | | | | | (M23)Test | | | | | | (M12)Test | | | | | (M23)Test | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Item No. | Error Responses % | | | | Cor. Rsp. % | Error Responses % | | | | Cor. Rsp. % | Item No. | Error Responses % | | | | Cor. Rsp. % | Error Responses % | | | | Cor. Rsp. % |
| | (1) | (2) | (3) | (4) | | (1) | (2) | (3) | (4) | | | (1) | (2) | (3) | (4) | | (1) | (2) | (3) | (4) | |
| 1 | 0 | 0 | 10 | 0 | 56 | 0 | 0 | 7 | 0 | 53 | 26 | 0 | 0 | 4 | 2 | 21 | 0 | 1 | 3 | 3 | 40 |
| 2 | 16 | 38 | 0 | 0 | 3 | 17 | 45 | 0 | 0 | 5 | 27 | 4 | 6 | 0 | 3 | 24 | 7 | 8 | 0 | 3 | 34 |
| 3 | 2 | 0 | 0 | 5 | 39 | 1 | 0 | 0 | 6 | 55 | 28 | 0 | 4 | 0 | 18 | 15 | 0 | 3 | 0 | 25 | 24 |
| 4 | 0 | 0 | 0 | 5 | 55 | 0 | 0 | 0 | 5 | 71 | 29 | 0 | 9 | 0 | 23 | 9 | 0 | 5 | 0 | 32 | 15 |
| 5 | 14 | 0 | 2 | 5 | 4 | 8 | 0 | 2 | 3 | 10 | 30 | 13 | 0 | 0 | 21 | 6 | 11 | 0 | 0 | 30 | 9 |
| 6 | 1 | 4 | 4 | 0 | 5 | 2 | 4 | 5 | 0 | 14 | 31 | 29 | 0 | 0 | 6 | 6 | 28 | 0 | 0 | 6 | 5 |
| 7 | 8 | 3 | 0 | 0 | 15 | 12 | 5 | 0 | 0 | 31 | 32 | 8 | 2 | 39 | 0 | 4 | 12 | 1 | 24 | 0 | 4 |
| 8 | 0 | 2 | 2 | 6 | 19 | 0 | 3 | 1 | 8 | 34 | 33 | 2 | 0 | 0 | 0 | 67 | 0 | 0 | 2 | 0 | 64 |
| 9 | 2 | 1 | 0 | 5 | 24 | 0 | 0 | 0 | 5 | 29 | 34 | 7 | 0 | 0 | 0 | 52 | 7 | 0 | 0 | 0 | 53 |
| 10 | 0 | 3 | 4 | 5 | 8 | 0 | 8 | 3 | 3 | 18 | 35 | 0 | 0 | 1 | 2 | 29 | 0 | 0 | 2 | 2 | 69 |
| 11 | 2 | 0 | 6 | 0 | 12 | 2 | 0 | 5 | 0 | 17 | 36 | 0 | 0 | 0 | 11 | 32 | 0 | 2 | 0 | 8 | 43 |
| 12 | 5 | 0 | 2 | 19 | 10 | 3 | 0 | 3 | 17 | 14 | 37 | 0 | 0 | 3 | 0 | 62 | 0 | 0 | 2 | 0 | 69 |
| 13 | 4 | 2 | 2 | 0 | 22 | 4 | 2 | 2 | 0 | 31 | 38 | 0 | 6 | 1 | 5 | 16 | 0 | 5 | 3 | 4 | 27 |
| 14 | 1 | 10 | 0 | 0 | 12 | 3 | 14 | 0 | 0 | 20 | 39 | 3 | 0 | 3 | 1 | 23 | 2 | 0 | 4 | 4 | 45 |
| 15 | 0 | 4 | 6 | 3 | 13 | 0 | 4 | 3 | 2 | 15 | 40 | 4 | 2 | 4 | 0 | 32 | 2 | 2 | 4 | 0 | 42 |
| 16 | 2 | 2 | 2 | 0 | 34 | 1 | 1 | 2 | 0 | 42 | 41 | 0 | 0 | 0 | 2 | 59 | 1 | 0 | 0 | 4 | 73 |
| 17 | 0 | 0 | 2 | 6 | 28 | 1 | 0 | 4 | 6 | 48 | 42 | 0 | 5 | 0 | 0 | 33 | 0 | 12 | 1 | 0 | 42 |
| 18 | 0 | 15 | 0 | 3 | 7 | 0 | 10 | 0 | 8 | 13 | 43 | 21 | 0 | 0 | 2 | 16 | 26 | 0 | 0 | 2 | 28 |
| 19 | 10 | 10 | 0 | 2 | 7 | 12 | 8 | 0 | 3 | 9 | 44 | 0 | 5 | 14 | 0 | 16 | 2 | 5 | 9 | 0 | 19 |
| 20 | 0 | 23 | 5 | 0 | 5 | 2 | 20 | 7 | 0 | 6 | 45 | 0 | 0 | 0 | 0 | 67 | 0 | 0 | 0 | 0 | 73 |
| 21 | 0 | 0 | 6 | 0 | 35 | 0 | 2 | 5 | 2 | 43 | 46 | 4 | 0 | 2 | 18 | 11 | 4 | 0 | 1 | 12 | 7 |
| 22 | 3 | 3 | 0 | 0 | 42 | 1 | 4 | 0 | 0 | 46 | 47 | 0 | 0 | 1 | 2 | 61 | 1 | 0 | 1 | 1 | 68 |
| 23 | 2 | 0 | 11 | 4 | 4 | 2 | 0 | 10 | 5 | 6 | 48 | 3 | 10 | 0 | 0 | 10 | 3 | 7 | 2 | 0 | 18 |
| 24 | 0 | 0 | 0 | 0 | 76 | 0 | 0 | 1 | 0 | 81 | 49 | 0 | 2 | 0 | 3 | 38 | 2 | 2 | 0 | 3 | 50 |
| 25 | 4 | 8 | 4 | 0 | 10 | 2 | 7 | 5 | 0 | 12 | 50 | 2 | 9 | 0 | 3 | 13 | 1 | 16 | 0 | 3 | 21 |

if pupils could identify the relationships among the load, the force, and the fulcrum in a second class lever. It is apparent from the figures in Table 18 that a substantial number did not understand this prior to instruction and although the per cent of cases who did respond correctly after instruction had increased a substantially larger proportion (about 75%) were either uncertain as to how the components in a second class lever might be arranged or they were vacillating.

Questions #28, 29, and 30 attempted to determine if students could conceive of one point on a rotating surface traveling farther and/or faster than another point on the same surface. Consistently, the pupils indicated that all points on the rotating surface (airplane propeller, bicycle wheel, fan blade) would turn at the same speed and that all points would travel the same distance. This view is inconsistent with an understanding of the principle implicit in the operation of the wheel and axle. This was confirmed by the very low correct responses to the test items #30, 31, and 32 which also were directly related to the wheel and axle principle.

It is important to note that there were some test questions in which the options were not incorrect answers. For example, question #42 asked the pupils to indicate which of a group of items exhibited some friction and the four options were: 1) fans, 2) roller skates, 3) airplanes, 4) all three of the above. Obviously all of these have some friction and the preferred answer would be to have the pupil indicate that he knew that all of these machines had some friction. On the one hand, it was not wrong to indicate that roller skates had friction; but the preferred answer was that all three of these machines had some friction. The intent of the question was to determine if the pupil could select the comprehensive answer rather than a particular instance as an answer.

The preceding remarks have cited the error response patterns which occurred on the machines test. Similar patterns have been noted by the researcher with respect to pupils' responses to test items on the electricity test and to the heat test. However, these patterns have not been discussed in this report.

### 6. Teacher Responses to Questionnaires About Instruction

Approximately 18 of the 20 teachers replied to the questionnaire following the unit of instruction for simple machines. Five Detroit teachers accounted for 25 classes in the sample and the suburban teachers accounted for 6 classes in the sample.

The plan of instruction for simple machines provided a tentative schedule of 18 school days which required 45 minutesperiods of instruction. This amounted to approximately 13.5 hours of instruction for simple machines. As shown in Table 19 the teachers completed the unit between 5 and 7.5 weeks. The median number of days per week of instruction was three. Most of the classes were conducted during periods of instruction of approximately 1/2 hour. The total time may be estimated to range from 7.5 hours of instruction to 12.5 hours of instruction in the Detroit schools. In the suburban schools, the total instruction ranged from 7.5 hours to 25 hours of instruction.

It should be noted that these totals may be exaggerated and very deceptive indications of the total amount of time spent in instruction. This discrepancy may occur because of interruptions from holidays (Yom Kipper, Veteran's Day, Thanksgiving) and other events which occurred in particular schools and interrupted the regularly scheduled plan of instruction. When the researcher met with the cooperating teachers, they indicated to him that when these interruptions did occur they tended to wait until most of the pupils had returned to class before proceeding with the instruction.

In their replies to all three questionnaires, the teachers indicated that they used the teaching protocol "teacher and pupil demonstration" most frequently in the Detroit schools and in the suburban schools. Often this particular teaching procedure was modified according to the circumstances of the teacher and involved teacher lectures and laboratory periods. In some classes, certain pupils made "science projects" or other exhibits at home and brought them to school to share with classmates.

Table 20 indicates the answers made by teachers to the questionnaire following their instruction on the topic of electrical energy. This unit plan specified instruction for 15 school days of approximately 45 minutes per day. That is, the unit plan required approximately 11.5 hours of total instruction.

In the Detroit schools the instruction lasted for approximately 6 or 7 weeks and the median number of days of instruction per week was three. The approximate length of each class period continued to be 1/2 hour and it was estimated that the approximate total hours of instruction in the Detroit schools ranged from 7 to 16.

In the suburban schools, the instruction extended from 3.5 to 7 weeks and the median number of days per week of instruction was three. The approximate length of class periods for instruction

Table 19

## SUMMARY OF TEACHERS' ANSWERS TO QUESTIONNAIRE ABOUT INSTRUCTION FOR SIMPLE MACHINES

| Detroit Teachers | No. Weeks of Instruction | Days Taught Per Week | Approx. Length of Class Period | Approx. Total Hours Instruction | Specific Classes Taught |
|---|---|---|---|---|---|
| Teacher #1 | - | - | - | - | 1,2,3,4 |
| Teacher #2 | 5.5 | 3 | 3/4 hr. | 12.5 | 5,6,7,8,88 |
| Teacher #3 | 5.5 | 4 | 1/2 hr. | 11 | 9,10,11,12,13,14,58 |
| Teacher #4 | 6 | 3 | 1/2 hr. | 9 | 15,16,17,18 |
| Teacher #5 | 5 | 3 | 1/2 hr. | 7.5 | 19,20,21,22 |
| Suburban Teachers | | | | | |
| Teacher #7 | 7 | 5 | 1/2 hr. | 17.5 | 23 |
| Teacher #8 | 7 | 4 | 1/2 hr. | 14 | 24 |
| Teacher #9 | 6.5 | 3 | 1/2 hr. | 10 | 25 |
| Teacher #10 | 7 | 4 | 1/2 hr. | 14 | 26 |
| Teacher #11 | 5 | 5 | 1/2 hr. | 12.5 | 27 |
| Teacher #12 | 6 | 3-4 | 1/2 hr. | 11.5 | 28 |
| Teacher #13 | 6 | 3 | 1 hr. | 18 | 32 |
| Teacher #14 | 6 | 3 | 3/4 hr. | 13.5 | 33 |
| Teacher #15 | 6.5 | 2 | 1/2 hr. | 7.5 | 34 |
| Teacher #16 | 5.5 | 3 | 1 hr. | 16.5 | 35 |
| Teacher #17 | 5.5 | 3 | 1 hr. | 16.5 | 37 |
| Teacher #18 | 5.5 | 3 | 1 hr. | 16.5 | 36 |
| Teacher #21 | 7.5 | 2 | 1 hr. | 15 | 38 |
| Teacher #22 | 5 | 5 | 1 hr. | 25 | 39 |
| Teacher #23 | 5 | 5 | 3/4 hr. | 19 | 40,41 |

*In the table above, the sign "-" indicates that no information was obtained for the category.

**Detroit Teachers taught 25 classes. Suburban teachers taught 16 classes.

Table 20

## SUMMARY OF TEACHERS' ANSWERS TO QUESTIONNAIRE ABOUT INSTRUCTION FOR ELECTRICITY*

| Detroit Teachers | No. Weeks of Instruction | Days Taught Per Week | Approx. Length of Class Period | Approx. Total Hours Instruction | Specific Classes Taught |
|---|---|---|---|---|---|
| Teacher #2 | 7 | 3 | 3/4 hr. | 16 | 5,6,7,8,88 |
| Teacher #3 | 6 | 4 | 1/2 hr. | 12 | 9,10,11,12,13,14,58 |
| Teacher #4 | 7 | 3 | 1/2 hr. | 10.5 | 15,16,17,18 |
| Teacher #5 | 6 | 3 | 1/2 hr. | 9 | 19,20,21,22 |
| Teacher #6 | 7 | 2 | 1/2 hr. | 7 | 1,2,3,4 |
| Suburban Teachers | | | | | |
| Teacher #7 | - | 5 | 1/2 hr. | - | 23 |
| Teacher #8 | 4 | 4 | 1/2 hr. | 8 | 24 |
| Teacher #9 | 4.5 | 3 | 1/2 hr. | 7 | 25 |
| Teacher #10 | 4.5 | 4 | 1/2 hr. | 9 | 26 |
| Teacher #11 | 5 | 5 | 1/2 hr. | 12.5 | 27 |
| Teacher #12 | 3.5 | 5 | 1/2 hr. | 9 | 28 |
| Teacher #13 | 5 | 2 | 1 hr. | 10 | 32 |
| Teacher #15 | - | 2 | 3/4 hr. | - | 34 |
| Teacher #16 | 7 | 2 | 1 hr. | 14 | 35 |
| Teacher #18 | 7 | 2 | - | 14 | 36 |
| Teacher #19 | 7 | 2 | 3/4 hr. | 14 | 37 |
| Teacher #20 | 7 | - | - | - | 33 |
| Teacher #21 | 6.5 | 3 | 1 hr. | 19.5 | 38 |
| Teacher #22 | 5.5 | 5 | 1 hr. | 27.5 | 39 |
| Teacher #23 | 4.5 | 5 | 3/4 hr. | 19.5 | 40,41 |

*In the table above, the sign "-" indicates that no information was obtained for the category.

**Detroit Teachers taught 25 classes. Suburban teachers taught 16 classes.

Table 21

## SUMMARY OF TEACHERS' ANSWERS TO QUESTIONNAIRE ABOUT INSTRUCTION FOR HEAT

| Detroit Teachers | No. Weeks of Instruction | Days Taught Per Week | Approx. Length of Class Period | Approx. Total Hours Instruction | Specific Classes Taught |
|---|---|---|---|---|---|
| Teacher #2 | 6 | 3 | 3/4 hr. | 13.5 | 5,6,7,8,88 |
| Teacher #3 | 5.5 | 4 | 1/2 hr. | 11 | 9,10,11,12,13,14,58 |
| Teacher #4 | - | - | - | - | 15,16,17,18 |
| Teacher #5 | 5.5 | 3 | 3/4 hr. | 13 | 19,20,21,22 |
| Teacher #6 | - | - | - | - | 1,2,3,4 |
| Suburban Teachers | | | | | |
| Teacher #7 | 7 | 5 | 1/2 hr. | 17.5 | 23 |
| Teacher #8 | 7 | 4 | 1/2 hr. | 14 | 24 |
| Teacher #9 | 5 | 3 | 1/2 hr. | 7.5 | 25 |
| Teacher #10 | 4 | 5 | 1/2 hr. | 10 | 26 |
| Teacher #11 | 5 | 5 | 1/2 hr. | 12.5 | 27 |
| Teacher #12 | 4 | 4 | 1/2 hr. | 8 | 28 |
| Teacher #13 | - | - | - | - | 32 |
| Teacher #15 | 7 | 3 | 1 hr. | 21 | 34 |
| Teacher #16 | 6 | 2 | 1 hr. | 12 | 35 |
| Teacher #18 | 6 | 2 | 1 hr. | 12 | 36 |
| Teacher #19 | 5 | 3 | 3/4 hr. | 11.5 | 37 |
| Teacher #21 | - | - | - | - | 38 |
| Teacher #22 | - | 5 | 3/4 hr. | - | 39 |
| Teacher #23 | 5 | 5 | 3/4 hr. | 19 | 40,41 |

*In the table above, the sign "-" indicates that no information was obtained for the category.

**Detroit Teachers taught 25 classes. Suburban teachers taught 16 classes.

continued to be 1/2 hour. The approximate total hours of instruction spent on electrical energy ranged from 7 to 27.5. Once again this range of total approximate hours of instruction may be exaggerated because of interruptions in the school program, holidays, teachers' institute meetings and other school events.

Table 21 indicates the teachers' responses to the questionnaire following instruction for heat energy. The unit plan called for 16 school days of instruction lasting for 45 minutes per day. In the Detroit schools the teachers spent approximately 5-1/2 weeks on this unit and taught it three days per week for about 1/2 to 3/4 of an hour per day. The total number of hours spent on this unit in the Detroit schools was estimated to range from 11 to 13 hours.

In the suburban schools, the unit consumed 4 to 7 weeks of instruction, which was presented for about 1/2 hour during each period of instruction. The median number of days of instruction was 3 days per week. The approximate total number of hours of instruction spent on the unit on heat ranged from 7.5 hours to 19 hours.

Table 22 provides a summary statement of the undergraduate studies of the cooperating teachers as well as indications of their previous studies in college science courses and their previous teaching experience. All teachers except one had completed a bachelor's degree and held a Provisional or Life Certificate to teach in Michigan. For teachers in the Detroit schools the number of college sciences courses ranged from 3 to 32, with a median of 13 courses. The years of teaching experience ranged from 1 to 19 years, with a median of 7 years. For teachers in the suburban schools the number of college science courses ranged from 0 to 10, with a median of 3 courses. The years of teaching experience ranged from 1 year to 32 years, with a median of 6 years.

## Table 22 EDUCATION AND TEACHING EXPERIENCE OF TEACHERS PARTICIPATING IN STUDY

| | Bachelor's Degree | Michigan Certificate | Number of College Science Courses Completed (approx.) | Teaching Experience (approx.) |
|---|---|---|---|---|
| **Detroit:** | | | | |
| Teacher 1 | yes | yes | 12 | 14 yrs. |
| 2 | no | yes | 3 | 19 yrs. |
| 3 | yes | yes | 32 | 8 yrs. |
| 4 | yes | yes | 12 | 6 yrs. |
| 5 | yes | yes | 3 | 4 yrs. |
| 6 | yes | yes | 14 | 1 yr. |
| **Suburbs:** | | | | |
| Teacher 7 | yes | yes | 3 | 27 yrs. |
| 8 | yes | yes | 0 | 9 yrs. |
| 9 | yes | yes | 2 | 6 yrs. |
| 10 | yes | yes | 0 | 19 yrs. |
| 11 | yes | yes | 0 | 32 yrs. |
| 12 | yes | yes | 0 | 15 yrs. |
| 13 | yes | yes | 10 | 2 yrs. |
| 16 | yes | yes | 5 | 1 yr. |
| 18 | yes | yes | 4 | 2 yrs. |
| 19 | yes | yes | 4 | 1 yr. |
| 21 | yes | yes | 6 | 2 yrs. |
| 22 | yes | yes | 1 | 6 yrs. |
| 23 | yes | yes | 7 | 3 yrs. |

## IV. DISCUSSION

### 1. Accomplishing Objectives of Study.

A. Objective #1 - The first objective was concerned with identifying several valid and significant generalizations about electricity, heat energy, and simple machines. This objective was achieved. Appendix F includes the specific generalizations which resulted from the selection procedures which were reported previously in Section II of this report.

One of the problems in achieving this objective was the semantic difficulties encountered in using words precisely for scientists and for children. The literature has indicated that honest differences of opinion exist between university scientists and educators who are concerned with making a set of ideas meaningful to a group of children in the elementary school. The writer has not resolved this difficulty. However, he has attempted to document the statements of generalizations so that the resulting statements have at least been considered from the perspective of the physicist, from the viewpoint of the science educator, and from the classroom teacher's point of view.

It should be noted that the generalizations stated in Appendix F are not to be considered immutable and final statements of these ideas. The English language has such facility that the same idea may be expressed in a variety of ways. The researcher has simply chosen one of the ways of expressing each of the major science generalizations. It is this same versatility of the English language in representing similar or identical ideas with different words, which seems to be at the heart of the disagreement between persons on one side who are concerned about accurate statements of generalizations or principles of science versus those persons on the other side of the issue who are concerned about forming meaningful and simplified statements of the same ideas in order to communicate with children.

B. Objective #2 - The second objective of the study was concerned with writing multiple-choice test items to provide estimates of pupils' understanding of the generalizations in Appendix F. This objective was accomplished. The three unit achievement tests are presented in Appendix J.

This was one of the most difficult tasks in the entire study. Each of the major science generalizations listed in Appendix F, may subsume many other, less complicated generalizations. Each of these larger generalizations is analogous to a major root from a large tree; and each major root has many, many branches. Each of the branches can legitimatly be considered a member of the larger root or generalization, as the analogy goes.

The multiple-choice test item will only permit one to collect evidence on one of the subsidiary generalizations. The writer has alluded to his subsidiary generalization as the "test item generalization". The hazard of overgeneralizing from a single test item or small number of items to the major science generalization should be apparent. The fact that a pupil recognizes that a pencil resting upon a desk is not doing work upon the desk is a modest piece of evidence to use to suggest that the same pupil understands the major generalization; "Work is done when a force moves an object."

Effort was made to compensate partially for the inherent limitation in the multiple-choice test question by developing a procedure which the researcher called "double precision scoring". This scoring procedure placed a premium upon the pupil being consistent over a period of time in the specific responses which he selected on the multiple-choice questions. In previous research (67,20), the researcher was impressed with what seemed to be contradictory results. It seemed that pupils would respond one way on a pretest and in interview situations shortly afterward they would respond quite differently, although no apparent reasons could be adduced for the inconsistency.

At this point, the researcher is inclined to believe that many pupils, like many adults including professors, are able to hold mutually inconsistent ideas in their minds and to maintain and assert those ideas with apparent disregard for the fact that they are logically inconsistent. In some of the interviews which have been conducted with pupils, certain children have used terms with one meaning in one statement and then in the next series of statements they have quite blithely used the same term for a substantially different purpose and meaning. This also may be noted in some of the transcribed interviews reported by Inhelder and Piaget (32). For example, a pupil may be discussing the Bohr concept of the atom, and begin to interchange the terms nucleus, electron, proton, positive charge, negative charge. Although a given pupil may be consistent for a large proportion of the time, even the most able student seemed to lapse into occasions when they were clearly inconsistent with their own views. For some children this pattern of inconsistency was a persistent practice.

In an analogous manner, it seems conceivable to the researcher that when taking multiple-choice tests, the same pattern of inconsistency may be prevalent throughout the entire test for the entire group of pupils. This pattern of inconsistency may be blatant in some children and uncommon for other children in the same classroom. Therefore, the lack of agreement of the pupil with himself apparently contributes error variance which is readily detected, and exaggerated perhaps, by the statistical formulas used in conventional estimates of test reliability.

In substance, the researcher was concerned that his judgements and inferences be based upon evidence, i.e., responses to test items, which the pupil has clearly identified as a firm and stable indicator of his opinions or views. For this reason the researcher was inclined to favor "double precision" scoring.

C. Objective #3 - This objective was concerned with constructing units of instruction on electricity, simple machines and heat energy to be presented to randomly selected classes throughout Metropolitan Detroit. This objective was accomplished. Appendix I provides the three units of instruction which were presented to all pupils in the study.

In their replies to questionnaires and their comments to the researcher, it seemed that the suburban school teachers considered the units of instruction and the apparatus which accompanied them to be a very helpful resource. They felt that it was very difficult for them to find the time to coordinate and assemble all the materials which might profitably be used in an adequate unit of instruction for one of the science topics. Therefore, even this modest collection of apparatus, filmstrips, and brief contacts with the researcher seemed beneficial in the judgement of the teachers in the suburban schools.

In the Detroit schools, the classrooms were ordinarily well-equipped with apparatus, science books and similar materials. However, several of these science specialists indicated that they felt that the organization of the units and the organization of the materials was beneficial to them. They also expressed concern about finding the time to assemble the materials and the instructional plan for presenting a given topic of instruction.

In general, then, the researcher was inclined to feel that the unit of instruction and the accompanying materials enabled the cooperating teachers to provide instruction on these topics which was as good or better than the instruction available to other classes of pupils in the population.

The second part of this particular objective was concerned with selecting samples randomly from Metropolitan Detroit. This objective was also accomplished and has been documented in

Section II of this report.

In selecting randomly throughout Metropolitan Detroit, the researcher was impressed with the diversity of teaching situations and the backgrounds of science preparation which seemed to characterize all of the teachers in the study. This has been documented in the previous section in Table 22. On the other hand, it was interesting to note that the analyses of variance for the unit achievement tests revealed modest differences in the success of pupils who received instruction in these diverse settings following the unit plan presented in this study.

It was obvious that there was some diversity in the teaching styles followed by different teachers, although most teachers followed a pattern termed "teacher pupil demonstration." The researcher had difficulty in obtaining explicit and verifiable information to determine what actually occurred in the various classrooms during the units of instruction. Certainly, more precise recording of classroom events should be undertaken in future studies of this type. However, in spite of these gaps in the information, the major differences which occurred among classes participating in the study can be explained largely in terms of socio-economic background and the pupils' achievement on standardized measures for reading, science, and verbal intelligence. These tests are reasonably precise indicators of the gross success of pupils in the information processing tasks which typify classrooms in the population of schools in this study.

The graphical analysis indicated rather clearly that the units of instruction tended to favor those pupils who were proficient in these information processing skills. It is impossible to say whether this was implicit in the unit plan and materials organized by the researcher or whether this was implicit in the instructional procedure and the classroom organization which characterized the schools of Metropolitan Detroit. In any event, it was quite clear that language facility was a major contributor to success in all of the classrooms participating in this study.

D. Objective #4 - This objective was concerned with making item analyses of the unit achievement tests in order to determine the per cent of pupils who understood each generalization before and after instruction. This objective was accomplished. The tables in Appendix A, B, and C provide these estimates to indicate probable success in understanding each of the generalizations before and after instruction.

The item analyses were undertaken to enable the curriculum planners to utilize the information which is ordinarily available to them so that they might make optimum decisions about the program appropriate for specific groups of pupils in their urban school communities. Therefore, the item analyses were undertaken initially for each grade level. Pupils in these grade groups were subdivided again into three categories (high, middle, low), according to their scores on the publisher's norms for standardized tests of science background, reading comprehension, and verbal intelligence. The socio-economic rating scale in Table 3 was used to classify pupils according to their school's socio-economic rating.

Although no specific information was collected, it was the writer's judgement that an increasing order of precision for these estimates of probable success would be made by estimates of official grade level, socio-economic background, verbal intelligence, reading proficiency, and science background information. The latter would probably provide the most precise estimates of pupils' probable success in understanding any of the ideas in the three units.

One of the problems involved in this study was the decision to use the categories mentioned above. In previous research ( 72), the writer recommended the use of "normative grade placement" of science concepts as a means of establishing an elementary school science program based upon pupils' probable success in understanding a set of ideas. However, during this study it became apparent that this view would not be widely accepted or implemented. In addition, the publisher of the test norms which had been used by the researcher decided to revise the tests. Therefore, the researcher elected to use the publishers' norms to make the gross classification of the sample into high 25%, middle 50%, and low 25% with respect to background information about science topics. It seemed to the researcher that this very rough classification could be achieved by most of the available power tests in science. It also seemed that this rough classification of pupils might be made by using the existing standardized tests of science information, even when those tests have claimed to measure problem solving or critical thinking in the sciences.

The researcher still believes that valid and reliable norms may be used to establish a scale which could be used profitably in making curriculum decisions. It should be quite clear that units of measurement are arbitrary and fixed by statute. It is perfectly conceivable that a set of test measurements, units, and instruments might be established by a knowledgeable and reputable agency of the federal government, e.g., National Science Foundation; and that these units of measurement and these instruments could be used profitably in measuring pupils' success in understanding the concepts and processes of science. Needless to say, appropriate safeguards would have to be established for the legitimate use of these measuring instruments.

In conclusion, the rough classifications of "high, middle, and low," were used in order to provide a subdivision of each achievement measure which might be meaningful to teachers and other curriculum planning personnel. The intent was to make these probability estimates as useful as possible to persons concerned with planning the elementary school science curricula.

One of the sources of error in classifying pupils for the item analyses involved pupils in the Detroit schools, where some of the classes included pupils at more than one grade level. For example, one class might have pupils in fourth grade and also include some children who were classified as fifth grade pupils. Other classes might have pupils classified as "4B and 4A". Since Detroit schools have a promotion policy which advances pupils one half grade in January, some of these pupils would be "fourth graders" in fall, 1965 and some of them would be "fifth graders" in the spring of 1966. This arrangement occurred only in the Detroit schools' sample and it involved three classes. The researcher made an arbitrary decision to classify a fourth grade group as "fourth graders" when they entered the project in the fall and they remained with the fourth grade sample for the entire year, even though some members of that particular class may have become "fifth graders" according to the records of the Detroit public schools.

If a group of youngsters started the unit with the official grade designation of "4A - 5B" or "5A -6B", then the researcher arbitrarly classified all pupils in each group according to the lower grade rating. That is, the "4A -5B" group would be classified with fourth grade pupils. The "5A -6B" pupils would be classified with fifth grade pupils.

Another source of error was the lack of empirical tests of the precision of all of the probability estimates which were included in Append. A,B, and C. Reliability estimates have been computed for the unit achievement tests by using grade groups, i.e., random samples of pupils from grades 4, 5, and 6. This was accomplished using the Monte Carlo procedure described in Section II (METHOD OF STUDY). Time and available funds did not permit the researcher to compute estimates of the reliability of the probability values when the norms for science background, reading comprehension, verbal intelligence, and socio-economic levels were used as the indicator of probable success. It was assumed that these estimates would be more precise than the grade level values, but no empirical tests were conducted to check the accuracy of this assumption. On the other hand, theoretical estimates of the precision of these estimates may be derived from the graph in Appendix D.

E. Objective #5 - Objective #5 was concerned with arranging the per cent correct responses in a form to serve as probability estimates that other pupils would understand the specific generalizations considered in this study. This objective was accomplished and it is documented in Appendices A, B, and C. The validity of the generalizations has been documented in the literature and in the judgement of professional scientists and educators. This has been described in Section II of this report and in Appendices F ,G. The relationship between the test item generalization and the major science generalization has been discussed in those same sections of the report. The validity of this relationship between the test item and the major science generalization has been based upon the judgement of professional science educators. Since the per cent correct responses relate directly to the test item generalizations and since the assumption of random selection of pupils was satisfied, then it is legitimate to consider these per cent correct responses as probability estimates that other members of the population will understand the specific test item generalizations used in this study. It is also legitimate to make inferences based upon this evidence that other members of the population will understand the major science generalization for which the corresponding test item was written.

One of the problems which occurred in conducting the item analyses and arranging the data into the various classifications, was that a very large number of calculations were required. Considerable care was needed in sorting the pupils' responses and cards into their appropriate categories and this provided a large number of occasions when clerical errors could easily enter. At least one month was lost during the analysis of data in attempting to track down and identify duplications of names and identification numbers of pupils in the study. In spite of the considerable effort that was invested in avoiding duplication and clerical error, the researcher is still fairly confident that some duplication and error still exist in the data. This is trivial in comparison with the number of students and test responses taken throughout the study. Proof reading the values cited in Appendices A, B, and C revealed recording errors of less than .1% and typing errors less than .5%.

It may be argued that these multiple-choice test items were not randomly selected from the large number of possible test items which might have been posed for each major science generalization. The researcher must concede that this is the case. These items were selected deliberately after considerable effort.

Moreover, each statement will have certain obvious flaws when examined closely by the sophisticated adult who is capable of examining a particular statement and generating subtle connotations and innuendos which are quite remote from the intellectual world of children in the age range from 9 years to 12 years of age.

If one considers the error response patterns summarized in Table 18 it might be appropriate to publish a complementary set of tables to indicate the probable errors which will be implicit in the minds of the pupils before instruction and after instruction in each of the topics included in this study. Such tables could be derived from the detailed examination of the error patterns which were discussed in Section III of this report.

F. Objective #6 - This objective was concerned with providing some estimate of the error of the probability values which have been presented in Appendices A, B, and C. This objective was accomplished. Appendix D includes a graph with several curves representing samples which vary from 6 to 1000 subjects per sample. Extensive research in computing these estimates of error for a proportion has been reported by Pearson and Hartley (58 ). The graph in Appendix D is taken from Tate and Clelland (83 ). It provides a means of estimating the range of variation for any proportion cited in Appendices A, B, and C. This assertion that the true proportion will occur within this range may be made at the 90% level of confidence. That is, the researcher may be 90% confident that a given proportion will fall within the range specified by the curves in Appendix D which correspond to the sample size used to compute the proportion.

It is important to avoid giving the impression that these probability estimates are absolute standards and irrevocable indications of pupils' success. This set of curves calls attention to the fact that any probability estimate is subject to error and on occasion the estimate or the trend may be reversed. It calls attention to the fact that one should indicate the amount of confidence which can be expressed in the precision of any estimate of probable success. These remarks are closely related to Carnap's (11) concept of "degree of confirmation".

Inspection of the curves in Appendix D indicates clearly that the range of variation for any proportion will depend directly upon the size of the sample used to compute the proportion, assuming that the requirement of random selection has been satisfied. The researcher has elected to keep fairly large samples to support each of the test item generalizations. He attempted to strike a balance between sub-dividing various categories (grade level, science background, reading proficiency, verbal intelligence, socioeconomic level) and making the classifications so broad that they would be of negligible value. It should be apparent, that if one starts with the sample of fourth grade pupils and sub-divides them into high, middle, and low categories for science background; and then sub-divides each of these categories into high, middle, and low classifications for reading comprehension; and then sub-divides these again into high, middle, and low classifications for verbal intelligence, and repeats the process of sub-dividing for socio-economic levels, the terminal node for that series of branches would have a very small number of persons representing the final sub-category. A large number of nodes at the end of that branching series would have no members. Therefore, it was necessary to strike a balance between sub-division of the classes and utilizing the additional information which was available about the pupils in the sample.

G. Objective #7 - This objective was concerned with publishing these probability statements in a form which would be readily usable by curriculum groups throughout the nation. This objective was accomplished. The documents in Appendices A, B, and C make it possible for teachers, administrators, and curriculum planners to utilize some of the available information which they have about their pupils to estimate their probable success in understanding one or more of the generalizations about simple machines, electrical energy, and heat energy. These appendices are part of the public domain and may be readily reproduced and utilized without fear of infringement of copyright.

It would be legitimate to apply these estimates to other samples of pupils in schools of Metropolitan Detroit. It is possible for curriculum planners in other urban centers to utilize these estimates, providing that their pupil populations and forms of classroom instruction are actually comparable to the schools in Metropolitan Detroit. Extrapolation of results from one population to another population which was not represented in the initial selection is hazardous. However, in the absence of other evidence, these results may be useful as a first approximation.

H. Objective #8 - This objective was concerned with using a computer program and the empirically derived estimates to make curriculum recommendations for each of the classes in the schools participating in the study. This objective was not accomplished. In a previous research project ( 71 ), the writer had reported a computer program which would make curriculum recommendations based upon probability estimates for generalizations about light energy. As the researcher continued the analysis of the data in this study, he became more impressed with the complexity of the teaching-learning situation and with the complexity of the network of accurate compeptions and inaccurate conceptions which seemed typical of each of the pupils in the study. When this very complex network of understandings and misunderstandings is amplified by 30 pupils per classroom and increased again by 20 or more classes in a given school, the complexity of this network is awesome.

It would be possible to define rather arbitrary "cut-off points", and then use these values to make decisions as to whether or not a particular generalization or concept would be taught to a particular class or in a particular school. However, it is the writer's judgement that this would be a superficial treatment of the problem. It would gloss over the large numbers of variables which are implicit in the minds of the pupils in the school. Indeed, it would be a facade which would be as deceptive as are many of the curriculum guides, which are displayed at various professional meetings. The printout from the computer would be irrelevant and deceptive as to the possible understandings and misunderstandings which are implicit in the minds of the 30 or more pupils in any elementary school classroom. Such a computer printout would be as unrealistic as the curriculum guide and about as unrepresentative of classroom reality as are those curriculum guides.

The preceding remarks may seem to be a clear indictment of the writer's previous recommendations ( 71) when it was initially recommended that the computer be used as to sketch a curriculum design. To some extent this is accurate. On the other hand, this is simply a matter of recognizing that considerable improvements have been made in the information processing power of computer systems since that recommendation was initially made. By utilizing this increased power the computer has enabled this researcher to consider the thinking of pupils in this study from a different vantage point and in substantially greater detail. A gross appraisal which was suggested in the earlier recommendations for the computer to sketch a curriculum design might have been appropriate in 1962; but with available hardware and software in computer systems, it would be quite inadequate.

To illustrate the possibility of providing a diagnostic profile of individual pupil's understandings and misunderstandings, the researcher wrote a computer program which will compute the double precision response patterns for the pupils' correct responses and for their incorrect responses. A sub-routine to this initial program will print the English statements so that anyone could call for the diagnostic profile of information in a language which he would understand. A hypothetical diagnostic profile is provided inAppen.G-9. A flowchart to illustrate the printing of the statements in English is included in Appendix G. A second hypothetical profile might call for any random sample of two or more individuals within the class, and this diagnostic profile is illustrated inAppen.G-10. It should be noted that a computer program has not been written to summarize and print the class diagnostic profile at this time. This deficiency is not due to inability of the computer systems to handle this, but it is largely attributable to the limited time and resources available to the researcher.

It is important to note that the computer is capable of providing a teacher or a group of teachers with a tremendously large volume of information about any single individual in their school or any collection of individuals in that school. It will do this if the information has actually been collected and organized in a form which will enable the machine to receive, store, and retrieve the information.

Indeed, teachers already face the dilemma of being overwhelmed by information about their pupils. Therefore, it is important that some evidence be collected in future studies to identify the information which is relevant to important decisions which ordinarily are made by teachers; and to discover whatever heuristic devices may be made available to teachers to exclude that information which is confusing and deceptive in its influence upon their decisons.

At the present time, science instruction in the elementary schools does not have sufficient status or high priority to command the services of information systems which are necessary for efficient instruction. This may change. For the present, however, the crude estimates in the tables in Appendices A, B, and C may be helpful to curriculum planners who are obligated to make decisions about which science topics may be taught to intermediate grade pupils.

The overwhelming evidence of this study is in clear opposition to Bruner's position that "...any subject can be taught to any child at any stage in his development in some effective and intellectually honest form." It may be that at some future date, there will be pharmaceuticals which will alter the chemical equilibrium of the brain so that children and adults can learn readily and without difficulty or misconceptions. It may be that at some future date, electrostatic generators will be so able to alter the electric field of the brain so that vicarious experiences and knowledge will be assimilated by children and adults without difficulty and these artificially "charged" impressions will be as permanent and meaningful as so called "concrete" experiences have claimed to be. However, it does not seem to this researcher that these events will come to pass in the next six to ten years. He does not believe that these exotic remedies or the prevalent computer-assisted instructional systems or the teaching machines or other highly publicized devices will become so prevalent and efficient as to substantially alter the instructional program in science for intermediate grade pupils during the next six to ten years.

During this next six to ten years, 25 to 50 million children will pass through the elementary schools of this nation. Teachers and curriculum planners must make decisions now that will influence the understanding and the misunderstanding of science topics of childrem presently attending those schools. To do nothing is, in itself, a decision. It is the researcher's opinion, that until persuasive evidence is available to indicate which pupils can profit from study of which science topics, curriculum planners should urge caution and practice caution in planning the science program for the elementary school children in their charge.

Many of the generalizations included in these units of instruction were much too difficult for these pupils. As long as large group instruction or class instruction is to be continued in the great majority of the schools, it brings with it the onus of inducing a large number of misunderstandings as well as a number of correct impressions and accurate understandings. Responsible curriculum planners must proceed with caution in deciding how they will gamble with the thinking of the pupils in their charge.

The results of this study indicate clearly that it is possible to identify the substantial variations which exist in the understandings and misunderstandings of topics which are to be taught to intermediate grade pupils. It indicates that the power of highly sophisticated computer systmes can be brought to bear upon the information processing problems posed by a model of efficient teaching-learning.

This study has not demonstrated how this "possibility" can be created. It has only demonstrated the feasibility of such a system. Until the possiblitiy has become a somewhat more plausible "reality" in schools in this population, the tables in Appendices A, B, and C would suggest a conservative estimate of the probabilities that large numbers of pupils can understand and retain the major generalizations presented in these units of instruction.

2. Discussion of Analysis of Variance Results.

A. Fourth Grade Unit Test Results. One of the consistent observations which can be made about the test results of the fourth grade classes is that pupils in low-scoring classes consistently came from the school community which was designated low socioeconomic. In particular, this referred to classes #19, 20. In the machines pre-test (M12) and post-test (M23), these two classes were consistently low. When the Bartlett's Test indicated that there was a significant difference among the variances of the grade 4 classes, the classes (#19,20) ordinarily were the ones which had the smallest class variance which contributed to the significant differences identified by the Bartlett's Test. Moreover, it was consistently the case that these classes had substantially lower mean scores than did the other fourth grade classes. This was the case in the electricity pre-test (E12) and the pre-test for heat (H12). It also occurred when the Bartlett's Test indicated significant differences in the electricity post-test (E23).

The analysis of variance results simply reiterate what was evident in the graphical analysis and which was reiterated in the standardized tests of reading comprehension, science achievement, and verbal intelligence. That is, pupils from low socio-economic communities are not as proficient as pupils from middle and high socio-economic communities in the information processes tasks which are implicit in these unit achievement tests and the standardized achievement tests. They are not as successful in symbol manipulation and in the conventional language processing skills. This is not a new finding, but merely reiterated what a large number of other studies (5) have already documented.

In the fourth grade group, class #9 and class #38 as well as class #10 on occasion, have distinguished themselves as scoring significantly higher than the other classes. If one considers their scores on the standardized tests for reading comprehension and science achievement and verbal intelligence, these classes include a substantial number of pupils who are very capable in the information processing tasks which are measured by these particular tests. These pupils were able to apply their skills in language and information processing to excell in their studies of these topics.

B. Fifth Grade Unit Test Results. Inspection of the analysis of variance tables for grade 5 pupils indicated that class (#1, 21) were consistently lower than the other fifth grade classes. This was the case on the machines pre-test (M12), machines post-test (M23), and when class #1 was no longer in the study because pupils in that class were promoted to another school, class #21 continued to score significantly below the other fifth grade classes on the remainder of the unit achievement tests.

Classes #1, 21 were from low socio-economic communities in separate parts of the city of Detroit. However, they shared this in common: they were substantially below their expected grade level for reading comprehension, science achievement, and verbal intelligence. This inadequacy in information processing skills revealed itself in the inadequacy to maintain achievement levels comparable with other grade five pupils in the sample.

Inspection of the graphs for class #2 seemed to support this impression. Class #2 had log-normal distributions for two of the unit achievement tests. When there was a normal distribution of scores, the average rate of change, as indicated by the slope of the curve for scores in class #2, compared favorably with the slope of the curves indicating average rate of change for other grade 5 classes.

Among the high-scoring classes, one would call attention to class #12, 32, 39, and classes #6, 15, and 26. The first group of these classes scored consistently higher than most of the other classes in the fifth grade sample on most of the unit achievement tests. The second group of these classes also tended to score higher than the other fifth grade classes, but were not as consistent as the first group in making high scores. Inspection of the mean scores on the standardized achievement tests for these six classes indicated that they were at or above the expected grade equivalent score in reading comprehension, science achievement, and verbal intelligence.

C. Sixth Grade Unit Test Results. Inspection of the analysis of variance tables indicated that for the machines pre-test (M12), classes (#22,3,4) were low in comparison to the other sixth grade classes. Classes #3 and #4 were consistently low in achievement throughout all of the tests for the units conducted in this study. It was not possible to obtain heat retention test data for pupils in classes #3 and #4 and this made it impossible to have complete test data for those classes for the (H23) test. These pupils had been assigned to several junior high schools throughout the city of Detroit, and it was impossible to locate them and administer the heat retention test. However, they were available for testing for machines, electricity, and the (H12) test for heat. Pupils in these classes were from low socio-economic school communities. In the one instance where the Bartlett's Test indicated that there was a significant difference in the variances of the sixth grade classes on a particular test, it was classes (#3,4,22) which accounted for this significant difference. These three classes made low mean scores and they also had low standard deviation scores which indicated that the variances in achievement within each of these classes was significantly smaller than the variances in the other sixth grade classes.

If one considers the achievement of these three classes on the measures of reading comprehension, standardized science achievement test, and verbal intelligence it indicated that pupils in these classes were significantly below the other sixth grade classes. This also indicated that the pupils in these classes did not have the skills required to process information in the large class setting which characterized instruction for this study.

Classes #58, 35, 37, 13, 40, and 8 distinguished themselves by consistently scoring high on the unit achievement tests. Inspection of the standardized science tests indicated that pupils in those classes also scored high on this test as well as high on the reading comprehension test and average on the verbal intelligence test. In indicated that the relatively strong background of science information and language skills were helpful to pupils in these classes during the instructional program.

In summary, it seems evident from the preceding discussion that success on any of the units depended upon certain information processing skills or language skills, as some persons may prefer to call them.

Pupils in low socio-economic communities were consistent in scoring below their counterparts in middle and high socio-economic communities. This is not to say that many of pupils in the low socio-economic community did not "succeed" in understanding and learning some of the materials presented in the units of instruction. However, it was indicated by the analysis of variance that these pupils were unsuccessful in making comparable gains. This is not to say that these pupils in low socio-economic communities cannot learn or understand these ideas. It does say that under existing conditions these pupils will consistently be less successful than their counterparts in the middle and high socio-economic communities. It does not say that all pupils in low socio-economic communities will score lower. On the contrary, there is evidence to indicate that some pupils are able to do as well or better than their counterparts in comparable grades. However, in terms of averages (as elusive as the term average may be), this study supports the results of other studies ( 5 ) which have indicated that pupils in low socio-economic communities will achieve less successfully than their counterparts in middle socio-economic and high socio-economic communities.

### 3. Discussion of Gain Scores

The distribution of gain scores for these three grade groups was very similar when one considers the relative gain. Although there were variations within a given class and among classes in the amount of gain made by individual pupils, it seems apparent that the average gain as a result of instruction for any one of the three units seemed to vary between 4% and 9%. If one may infer that the achievement tests provided adequate estimates of the amount of understanding or learning which occurred as a result of instruction, then one may infer that an average of 4% to 9% of all of the content which was presented to children during the instructional program was understood and retained. That is, average gains of 4% to 9% were made in pupils' understanding.

A gain of 4% to 9% may seem to be a very modest improvement. However, if one considers the fact that approximately 10% of the school week was invested in study of any one of the topics included in this project, then it appears that an investment of 10% of study time will precipitate an average gain of 4% to 9% for intermediate grade pupils. It is important to note that if this is the average gain, there were certainly youngsters who made great progress and achieved substantially larger gains. There was a corresponding group of youngsters who gained little or nothing from the unit of instruction. Indeed, the evidence indicated that there was a group of youngsters who formed and retained several misconceptions as a result of the instruction.

It is the researcher's view that this discrepancy between actual gain or loss as a result of instruction should be primary consideration of persons who seek to develop a science program for children in the elementary schools. This instruction may be considered appropriate for those youngsters who made "reasonable gains" as a result of instruction. The exact definition or explication of the meaning of the expression, "reasonable gain" must be considered carefully by those persons responsible for organizing the elementary school curriculum.

Table 23 was compiled by subtracting each pupil's double precision score of correct responses to a particular unit test from the total possible 50 correct responses, and computing a proportion to estimate the per cent of the total test which was unknown to the pupil before and after instruction. The table shows the mean proportions of information unknown by the pupils prior to instruction ranged from 71% to 87%. It indicates that there was a substantial range of about 5% to 9% in the differences in initial scores made by fourth grade, fifth grade, and sixth grade pupils prior to instruction in one of the topics.

At the conclusion of study, the mean proportions ranged from 63% to 84% of the test items unknown to pupils after instruction had concluded. In each case the higher grade group concluded instruction by comprehending and retaining more than did the lower grade group. Mean gain scores also tended to favor the fifth grade pupils over the fourth grade pupils, as well as the sixth grade pupils over pupils in the fifth grade or fourth grade.

It should be remembered that in each grade level there were individuals who entered with considerable previous knowledge of the topics to be presented and they varied in the amount of gains. There were other pupils in each grade level who entered with very

Table 23 MEAN PER CENT OF TEST UNKNOWN BY PUPILS AT START AND CONCLUSION OF EACH UNIT

| | Mean Scores (Per Cent) | |
|---|---|---|
| | Per Cent Unknown Before Instruction | Per Cent Unknown After Instruction |
| Grade 4 | | |
| Machines Test | 84% | 77% |
| Electricity Test | 87% | 84% |
| Heat Test | 80% | 75% |
| Grade 5 | | |
| Machines Test | 80% | 70% |
| Electricity Test | 83% | 77% |
| Heat Test | 74% | 68% |
| Grade 6 | | |
| Machines Test | 75% | 67% |
| Electricity Test | 81% | 73% |
| Heat Test | 71% | 63% |

large amounts of the test material unfamiliar to them; and they concluded their studies with varying amounts of improvement, i.e., some made remarkable improvement while others seemed to regress or make no improvement.

The previous remarks have dealt exclusively with levels of success of pupils in different grade groups. If one wishes to consider the success of individual pupils, this is a much more complicated task. The reader must consider the tree diagram shown in Figure 20 which indicates the possible response pattern to a single test item on one of the unit achievement tests. This tree diagram has 36 possible response patterns for a single test item administered to provide a pre-test, post-test, and retention test measurement.

If this number of possible response paths is multiplied by a factor of 150 for the total number of test items on all three unit achievement tests, then this indicates the possible response paths, available for a single pupil on the three unit achievement tests. If one wishes to consider 100 pupils at random from the group, then the previous total must be increased by a factor of 100. The numbers of elements in such a task is not impossible to analyze, but it is well beyond the objectives and expectations stated for this research project or anticipated for this research project.

Several other questions occurred to the researcher to pursue, but this was not possible under available time and resources. At this point in the project, one can only pose these questions and comment briefly upon them in the discussion. Close inspection must wait for a later study. For example, consider the following question. When a pupil made improvement after instruction, did he improve by making more correct responses to relatively simple test questions, i.e., (probability of success $\geq$ 50%)? It's conceivable that one or two correct responses to rather difficult questions (probability of success $\leq$ 25%) could signal a profound insight into the major generalization being measured by the test item. Other questions might be posed about the complexity of the error responses made by pupils. Certainly some of the basic misunderstandings could lead to considerable confusion and frustration on the part of pupils trying to interpret the conventional models presented in science textbooks or in class discussions. For example, some pupils clearly misunderstood the model of the Bohr atom, with a positively charged nucleus, which has one or more negatively charged electrons traveling around the nucleus. Some pupils considered the nucleus to be called an "electron", and that positively charged particles called "nucleus" were traveling around the outside of it.

This is a clear misconception of the model, and subsequent discussions which attempt to build upon understanding of this model can only lead to thorough confusion in the minds of children who have thus misinterpreted the model. Misconception piles upon top of misconception with only a modest prospect that someone or some event will help the child bring an ordered arrangement into his thinking.

### 4. Instruction by Classes with Science Specialist and Without Specialist

Since there was not a suburban class which had pupils from low socio-economic communities and there was not a Detroit class which had pupils from a high socio-economic community, the clearest comparison between these two types of instruction was evident in classes serving middle socio-economic communities. These could be compared at the fourth, fifth, and sixth grade levels.

At each of these grade levels, there were instances in which significant differences occurred among classes having the same science teacher and there were instances in which significant differences occurred between classes having different science teachers. In no instance was there a consistent tendency among the middle socio-economic classes to establish significantly higher scores in favor of classes receiving instruction from the special science teacher or in other classes receiving instruction from a non-specialized science teacher. Inspection of the analysis of variance tables in the preceding sections did not reveal significant differences among any of the classes in the middle socio-economic communities which might be attributed to having a special science teacher or having a non-specialized science teacher.

If one accepts the proposition that a person charged with teaching a single topic can become more proficient at teaching that single topic than another person charged with teaching several topics, then it is reasonable to ask: Why didn't the science specialist produce classes which scored substantially higher than the classes taught by non-specialized teachers?

Several possible explanations may be offered, but the writer will content himself with the following interpretation. The previous training of the science specialists and the abundant supply of materials at their disposal made it possible for them to provide science learning experiences superior to their counterparts in the suburban schools, in the judgement of the researcher. However, the science specialist had to conduct instruction in classes of 30 or more pupils for relatively brief periods (30 to 50 minutes) and to a large number of these classes each day. His energies and talents were distributed over a large number of pupils, with a corresponding dilution of his influence upon any single pupil. It is analogous to sprinkling a football field with a gallon of water.

In the suburban school communities, the teachers' energies and talents were distributed over a large number of subjects and science was only one of those subjects. Since much of the planning and organization of materials had been done for the teacher by the researcher, and the customary instructional organization was for large groups, i.e., class size of 25 pupils or more, the precision of instruction delivered by the suburban teacher was easily comparable in quality to the precision of instruction deliverable by the science specialist under his teaching circumstances.

5. Teacher Experiences and Achievement on the Unit Tests

Table 22shows the education and teaching experience of the teachers who participated in the study. With one exception all teachers had completed a Bachelors Degree and all of the teachers had a Michigan Provisional Certificate or a Michigan Life Certificate. Inspection of the number of college science courses and the analysis of variance for classes in grades four, five, and six does not indicate a significant relationship between total number of hours completed in science and success on any of the Unit Achievement Tests.

For example, Teacher #3 had the highest number of college science courses completed, and he was a science specialist teaching in the Detroit schools. In one of his fourth grade classes (#9), pupils scored significantly higher than pupils in another class (#10) which also received instruction from that science specialist. Pupils in class #9 had very high scores on the standardized science achievement test. Class #10 scores on the standardized tests were comparable to the other grade 4 classes and these pupils did not score significantly higher on the unit achievement tests than other comparable fourth grade classes in middle or high socio-economic communities.

For pupils in the low socio-economic community, one science specialist teacher had extensive teaching experience (14 years) and a substantial number of college science courses completed (12). Another science teacher working in Detroit schools with pupils in low socio-economic communities had completed a small number of science courses (3) and had 4 years of teaching experience. A third teacher has an extensive background of undergraduate studies in science and was in the initial year of teaching. In each situation, the pupils in those classes scored significantly lower than pupils at the same grade level in middle socio-economic communities in which the science specialist was used. Those same classes scored significantly lower than pupils in the same grade in middle or high socio-economic communities, when science instruction was presented by a non-specialist.

This leads the researcher to the conclusion that under existing conditions in schools throughout Metropolitan Detroit, the number of college science courses completed or the years of teaching experience are not indicative of success in the study of science under the conditions prevailing in this study.

### 6. Time Devoted to Instruction

Tables 19 thru 21 provide summaries of teachers' answers to questionnaires following their instruction for the units of simple machines, electrical energy, and heat energy. These tables indicated that all teachers spent about the same amount of time during a class period of instruction. The approximate total hours of instruction varied considerably according to the teacher's reports.

The suburban teachers apparently spent more total hours devoted to classroom instruction than did the specialist teachers in Detroit. For the suburban teacher, a median of approximately 15 hours of instruction was devoted to the machines unit. For the Detroit specialist, the median was 10 hours. For electricity the suburban school teacher spent a median of 13 hours of total instruction. The Detroit science specialist spent a median of 10.5 hours of total instruction for electricity. For heat energy the Detroit teachers spent a median of 13 hours for total instruction. For the suburbs, the teachers spent a median of 12 hours of total instruction for heat.

If one considers the amount of time spent by the various teachers in instruction for their respective classes and the levels of success indicated by the preceding analysis of variance, there does not seem to be any substantial relationship between amount of time spent in study of some particular topic and success on one of the achievement tests for the topic.

It should be noted that statistical tests were not made to determine whether or not these relationships between number of college science courses, teaching experience, total amount of time invested in instruction were significantly related to success on any of the achivement test variables. These conclusions were based upon inspection of the analysis of variance tables and tabulations of teachers' responses to the questionnaires.

# V. CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

## 1. Conclusions Regarding Pupils' Success On Unit Achievement Tests

A. At each grade level there appeared to be one or more classes in which the pupils scored significantly higher than the other classes at the same grade level. High-scoring classes occurred in Detroit schools and in suburban schools.

B. Pupils who were low on the unit achievement tests were ordinarily low on the standardized measures of reading comprehension, science achievement, and verbal intelligence.

C. Pupils in low socio-economic communities scored significantly lower on the unit achievement tests than did their counterparts in the same grade in the middle or high socio-economic communities.

D. When the Bartlett's Test indicated that there were significant differences attributable to the variances of scores among the classes, the low socio-economic classes consistently had smaller variances and lower mean scores than did the other classes at the same grade level.

E. There were no significant differences in the achievement of pupils in grades 4, 5, or 6 of the middle income communities when they were taught by a science specialist or when they were taught by a teacher who was not a specialist in teaching science.

F. There was no significant differences in the achievement of pupils in grades 4, 5, or 6 to indicate that the number of years of teaching experience, previous college undergraduate science courses, or total hours a unit was taught had enabled a particular class to excel on that unit achievement test..

G. Sex differences in achievement on the unit tests were sporadic and tended to occur at the beginning on the pre-test for a particular unit. When these differences did occur, they tended to favor the males scoring higher than the females; however, this superiority ordinarily disappeared and was not prevalent on the post-tests.

### 2. Conclusions Regarding Item Analyses

A. Double precision scoring made it possible to identify those pupils who appeared to understand the test item generalizations before instruction as well as those pupils who understood the same generalization after instruction and retained that understanding for three to five months.

B. The test item generalizations which were included in the study ranged from those which were simple (probability of success 70% or more) to those test item generalizations which were difficult (probability of success 25% or less).

C. There was a high positive relationship between pupils' success on the pre-unit test and their success on the post-unit test.

D. There was a substantial positive relationship among the various unit achievement tests.

E. Use of the confidence belts in Appendix D made it possible to estimate the probable error for each of the probability estimates which are listed in the tables in Appendices A, B, and C in the study.

F. At least four patterns were evident as a result of the item analysis of pupils' correct responses: 1) For some test items the pupils did not substantially alter their success before instruction and after instruction, 2) For some test items the pupils in grades five and six scored substantially higher than pupils in grade four without having substantial differences between grade five and grade six pupils, 3) For some test items there was an increasing order of probability of success from grade four to grade five to grade six, 4) A fourth pattern was noticeable in which there was a substantial increase in the per cent correct responses to a test item for all grade groups from the pre-test to the post-test.

### 3. Conclusions Relating to Pupils' Error Patterns

A. It was possible to identify consistent misinterpretations which pupils made before instruction as well as those which they made directly after instruction and retained for three to five months.

B. The inspection of the error responses for a given grade group indicated that when the probability of success was less than 25%, a substantially large number of pupils selected incorrect responses and retained those response patterns for three to five months. When the per cent correct responses to a test item occurred at the 50% mark or above, the per cent of error responses was modest.

C. A substantial proportion of the pupils at each grade level either changed their minds or did not understand several of the test item generalizations. This is particularily evident when the double precision correct response accounts for 10% or less in a sample and the double precision error response accounts for 10 to 15% in a sample. This clearly indicated that 75% of the sample were confused or uncertain about the test item question and the conventional answer.

D. Several of the ideas included in these units of instruction were apparently too difficult for a substantial number of the intermediate grade pupils who were taught under large group conditions in the schools in Metropolitan Detroit.

E. A computer program may be used to identify and state in English the test item generalization which is understood by pupils according to their item responses, as well as those test item generalizations which are clearly misunderstood by pupils. However, it is apparent that the computer can deliver large volumes of information about a pupil, and teachers will need help in determining which information they want to consider in making a specific decision.

### 4. Conclusions Regarding Pupils' Gain Scores

A. The unit achievement tests indicated that pupils in grades four, five, and six began instruction with 80 to 90% of the content not understood and they concluded instruction with 65 to 75% of the content not understood.

B. The mean gain scores made by fourth, fifth, and sixth grade pupils ranged between 5% and 10%. If the unit achievement test can be considered an estimate of the total number of ideas understood and retained out of an entire unit of instruction, then it seems to indicate that pupils gained 5% to 10% of the entire set of ideas presented in the unit.

C. It seems to be a rule of thumb, that if large group instruction is to consume 10% of the pupils' school week, then the average gain for those pupils will be between 5% and 10%.

D. Differences between pre-test and post-test scores indicate that there was considerable diversity among individual pupils in each grade level in the per cent gain made. Some pupils entered with 95% of the material unfamiliar and unknown to them as indicated by the pre-test and concluded the study with 95% of the materials unfamiliar and unknown to them.

There are some indications that those pupils may have developed more misunderstandings than they had when they began instruction.

E. One group of youngsters entered with 90% to 95% of the content unfamiliar and unknown to them as indicated by the pre-test, and made gains of 20% to 30% as a result of the large group instruction. Another group entered with 50% to 60% of the content unfamiliar to them and concluded instruction with 50% to 60% of the content unfamiliar to them. Another group entered instruction with 50% to 60% of the content unfamiliar to them as indicated by the pre-tests and concluded the unit of instruction with 30% to 40% of the material still unfamiliar to them.

### 5. Conclusions Resulting from Graphical Analysis of Data

A. Graphical analysis of the data provided additional checks to enable the researcher to interpret changes in achievement which occurred within classes.

B. Graphical analysis indicated that for the majority of the classes, a normal distribution was a good approximation of the distribution of pupils' scores before and after instruction. However, several variations including log normal and skewed distributions also were required in order to define explicitly the pattern of scores within a given class.

C. Among those classes which had normal distributions on the pre-test and normal distributions on the post-test, the most frequent pattern involved an increase in the median score from the pre-test to the post-test accompanied by an increase in the slope (average rate of change) and this was designated as hypothetical case #6. This clearly indicated that the portion of the class above the median on the pre-test made significantly larger gains than did the portion of the class below the median on the pre-test.

D. Among the classes having normal distributions on the pre-test and normal distributions on the post-test, the second most frequent pattern occurred in classes where the median score was significantly increased on the post-test but the slope or average rate of change was not substantially altered. This indicated that the entire group made a significant change, but that the improvements were distributed evenly throughout the entire class.

E. The largest number of patterns noted were those in which a normal distribution occurred on the pre-test and a normal distribution occurred on the post-test. There did not appear to be a large concentration of other combinations involving normal, log normal, or skewed distributions.

F. When skewed distributions did occur, these were consistently positively skewed distributions. For pupils in the middle and high socio-economic communities they never coincided with significantly lower class scores as indicated by the analysis of variance. However, when skewed distributions did occur for pupils in the low socio-economic communities, they frequently did coincide with significantly lower scores as indicated by the analysis of variance.

## 6. Implications of Study

A. One of the salient implications of this study was that the conventional classroom requires a rather sophisticated information system in order to approach reasonably efficient operation in identifying individual patterns of pupils' thinking. Throughout the school day, pupils are providing teachers with information about themselves and with indicators to show how their instructional program should be designed. However, teachers must rely upon relatively crude techniques for collecting, analyzing, and retrieving this information; therefore, these insights provided by pupils pass relatively unnoticed.

This study clearly indicated that optical scanning equipment can be utilized to encode categorical information about pupils' understandings of science generalizations. Computer analysis of these categorical responses enabled one to extract considerable information from these responses. Computer printouts in English can indicate the individual's understandings and misunderstandings. With the storage and retrieval systems which presently exist, this information about individuals or groups can be retrieved rapidly and delivered to the classroom teacher to facilitate decision-making.

It will take a substantial amount of time to develop ways of determining which information is clearly relevant to the various decisions which are made by teachers, as managers of the instructional program. However, considerable progress can be made with existing "know how" and heuristic adaptations.

Without an adequate information system to collect and analyze the tremendous amounts of information which consistently bombard the classroom teacher, coupled with the voluminous burden of clerical details, most teachers are forced to "pace" themselves in order to survive the rigours of the teaching-learning situation in contemporary classrooms.

To be sure, classes can be assembled. Teachers can meet with classes. Papers can be distributed, marked, scored, and grades assigned. Television sets may be turned on and permitted to run ad nauseam.

Undoubtedly, many pupils have been able to learn a great deal under these circumstances and those types of pupils will continue to succeed in spite of the circumstances. However, the evidence in this study suggests that with precise delineation of pupils' understandingsand misunderstandings in science, as well as in other curriculum areas, it is possible to utilize our available technology and our available human resources to enable pupils to achieve rates of learning which would be exponential.

B. Another implication of this study relates to the use of the science specialist in the Detroit Public Schools. In the judgement of the researcher, the Detroit Public Schools have a reservoir of the most able science specialists and the best equipped science rooms in any urban school district in the nation. However, the time and energies of these teachers is distributed over large numbers of relatively young children, who in many cases are not living under stable family conditions. Under these circumstances, the science specialist cannot concentrate his talents upon the tasks which he is uniquely equipped to undertake, i.e., teach science. The evidence indicates that his efforts are comparable to the efforts of other college graduates with modest preparation and study in the physical and biological sciences.

It would seem to be appropriate to re-examine the role of science in the elementary schools of Detroit. It might be possible to utilize television or films or other mass media, in order to release the science teacher to work with fewer children and for longer periods of time. It might be appropriate to consider excluding formal instruction in science from some of the elementary school grades in order that the talents of the science specialist can be brought to focus upon the task of teaching science to fewer children.

It is a superficial assessment to think that because a class of pupils meets with a science specialist for a certain number of minutes per week that they are learning "science" and getting something beneficial in science instruction.

C. Another implication of this study is relevant to publishing companies who prepare textbooks for the elementary schools. It suggests that they reconsider the content of their textbooks, at least for the three physical science topics touched upon in this study and for the intermediate grade group of children. It seems reasonable to inquire into the empirical basis for the content which is normally included in the elementary school textbook series.

It seems to this researcher that the publishers of elementary school textbooks and their authors have enjoyed an immunity from critical and penetrating appraisal of the evidence which supports their publications. Since the leading science educationists have a vested interest in improving the quality of these publications, it seems appropriate that these science educators should take the initiative by urging that intensive and representative research be undertaken to establish valid and reliable evidence of the contributions of their publications. Tremendous amounts of money are being invested in the "education market". The results of this study indicate that it is possible to collect evidence to document the successes and the failures of science instruction in representative classes of urban schools. In the judgement of this researcher, it is important for curriculum committees, who make recommendations for purchasing one or more series of textbooks, to ask for hard and persuasive evidence to indicate the usefulness of these instructional materials with specific groups of pupils.

D. Another implication of this study is for experimental groups who are probing to discover new ways to improve teaching one or more science topics to elementary school children. As mentioned previously, this study has provided a set of "bench marks" which may be utilized relative to the three topics in physical science which were presented in this study. It may be that programmed instruction, computer-assisted instruction, or one of the "process" oriented approaches to teaching science will be able to improve substantially upon the probability estimates which have been reported in the present study. It may be that teaching one or more of these generalizations for a prolonged period of time, i.e., three weeks, six weeks, three months, may alter substantially the probability estimates which have been reported. These probability estimates are certainly not absolute standards to be adhered to rigidly, and such replications or extensions of this research would be welcomed by this researcher.

## 7. Recommendations

A. It is recommended that a comprehensive study be undertaken to provide similar "bench marks" to indicate the probable success of teaching major generalizations from other science disciplines, i.e., biology, chemistry, astronomy, geology. Such a study would seek to identify salient topics and generalizations in each of these disciplines, following a procedure of documentation and consultation which was defined in the present study. These estimates should be collected over a period of at least three years and such a study should be undertaken soon.

B. It is recommended that a pilot school be established in which a computer-based information system, coupled with appropriate microfilm storage and retrieval units, could be established to explore the effectiveness of diagnosing pupils' understandings and misunderstandings and altering the instructional program so that these understandings or misunderstandings could be dealt with explicitly and on an individual basis. It is suggested that interviews and similar evaluative techniques be employed to supplement multiple-choice test questions which have been utilized by the researcher in the past. This would provide an additional check or series of checks upon the accuracy of the results and the conclusions.

C. Obviously, it would be desirable to have independent replications of the present study to indicate deficiencies or limitations which the researcher has identified or neglected to indicate. Replications of the same study in other urban centers such as New York, Los Angeles, and Chicago could be very helpful and enlightening.

It would be valuable to have this study replicated but with the addition of one or more of the promising and new approaches to classroom instruction, i.e., computer-assisted instruction, programmed instruction. Intensive studies of the same topic over a long period of time should be conducted to determine the extent to which these probability estimates may be altered by prolonged instruction of the same topic.

D. It is recommended that further research be undertaken to follow the error patterns which were explicitly identified in this study. This study has only hinted at the persistent nature of the gross misconceptions which characterized some pupils in the study. It would be important to determine the extent to which these gross misconceptions evolve into active interference with desirable learning patterns. Moreover, such studies should undertake to determine the emotional loadings which accompany the persistence of uncorrected error patterns. It seems to the writer that he would soon learn to hate the subject called "science instruction," if he was forced to attend classes where he consistently failed to comprehend what the teacher was explaining or demonstrating or trying to help him learn. The emerging instructional technology has the capability of identifying these patterns of error so that instruction can be directed precisely to the pupil's inadequacy or to a point which will enable him to extend his proficiency.

## VI. SUMMARY

A. Problem - This study was concerned with the problems created by a lack of empirical evidence to indicate which topics in the physical and biological sciences can be taught to elementary school children with reasonable expectation that they will understand, retain, and use those ideas to interpret the world in which they live. There is little empirical evidence to indicate which of these science generalizations can be taught by using the available teachers, time, and material resources which have been committed to science education in the schools in Metropolitan Detroit.

Specifically, this study was concerned with identifying certain generalizations about simple machines, electrical energy, and heat energy; and securing probability estimates that randomly selected classes of pupils in Metropolitan Detroit would be able to understand and retain those ideas.

B. Objectives of Study - There were eight specific objectives in this study.

1. Identify several valid and significant generalizations about electricity, heat energy, simple machines.

2. Construct multiple-choice test items to provide estimates of pupils' understanding of those generalizations.

3. Organize units of instruction for these topics and carry out instruction with randomly selected classes in Metropolitan Detroit.

4. Use item analyses of the unit tests to estimate probable success of pupils in understanding these generalizations before and after instruction.

5. Use these per cent correct responses to form probability statements that other pupils in the population will understand a specific generalization.

6. Provide estimates of the error of these probability statements.

7. Arrange these probability statements and science generalizations in a form which could be readily used by curriculum planning groups throughout the nation.

8. Use a computer program and the empirically derived probability estimates to make tentative curriculum recommendations for the classes in the participating schools.

### C. Methods of Study

1. Generalizations were selected that were considered to be appropriate for pupils in grades 4 through 8. Each statement was documented as being significant according to its presence in one of two college physics textbooks written by prominent physicists. The statements were documented as being present in the textbooks of prominent science educationsits. The statements were also documented as being valid and significant in the judgement of two of the following consultants: university physicist, science supervisor, and science teacher.

2. A stratified random sample was selected from the schools of Metropolitan Detroit and this included approximately 1,200 pupils in grades 4, 5, and 6. The pupils were selected according to strata for the city of Detroit where science was taught by science specialists and the suburbs where science was taught ordinarily by a non-specialized classroom teacher. The strata included low, middle, and high socio-economic school communities, in which the low socio-economic community was composed primarily of Negro pupils. The middle and high socio-economic communities were composed primarily of Caucasian pupils.

3. Teachers were provided with an instructional plan, filmstrips, science kits of apparatus, and brief consultations with the researcher to discuss the general plan of instruction. Teachers were free to impliment the instruction according to their teaching circumstances, but they agreed to follow the unit plan in general. The three units for simple machines, electrical energy, and heat energy were presented during the school year 1965-1966 to all intermediate grade pupils in the sample.

4. Multiple-choice tests were written by the researcher for each of the major ideas in the units of instruction. Research assistants administered the pre-tests and post-tests. They also administered a retention test three to five months after instruction had concluded for a given unit. Teachers were not present in the classroom during any of the testing. Standardized tests of reading comprehension, science achievement, and verbal intelligence were also used.

A procedure known as "double precision" scoring was devised by the researcher to score pupils' responses on the unit achievement tests. The researcher wrote a computer program which would examine a pupil's response to an item on the unit test administered before instruction as well as after instruction had concluded. The pupil would be credited with a double precision correct response on the pre-test, if he selected the same correct response to the same test item before and after instruction. The program examined the pupil's response to each item on the post-test and on the retention test. It credited the pupil with a correct response on the post-test, if he selected the same correct response on the post-test and on the retention test.

Validity of the test items was based upon the judgement of a university physicist, a science supervisor, and a classroom teacher. Reliability of each unit achievement test was estimated by a Monte Carlo simulation procedure which was devised by the researcher.

An estimate of the probable error of each proportion has been provided so that the reader may estimate the range for each probability statement with 90% confidence that the "true" proportion or probability value lies within that range.

### D. Results

1. The main results for this study are the three sets of tables included in Appendices A, B, and C, which provide probability estimates of intermediate pupils success in understanding major ideas about simple machines, electrical energy, and heat energy. Inspection of the correct responses indicates that there were at least four distinct patterns: 1) For many items there was a consistent improvement in the per cent correct responses from the pretest to the post-test for each unit achievement test. 2) For some items there was a tendency for a higher probability of success to occur for pupils in the higher grade groups, i.e., grade 6 over grade5, grade 5 over grade 4. 3) There was a tendency on some of the items for fifth and sixth grade pupils to be very similar in proportion of correct responses and be significantly higher than pupils in the grade four sample. 4) There were items which had a pattern indicating no significant increase in the proportion of correct responses on the pre-test or on the post-test. In this group, there were items in which there was also no significant difference between the probability of success of pupils in grades 4, 5, or 6.

2. A computer program was written by the researcher to provide a diagnostic profile for a single individual according to his correst responses and his incorrect responses. This profile of understandings and misunderstandings could be printed in English statements which could be read by the classroom teacher.

3. The study revealed a pattern of error responses for pupils and for groups of pupils. Some of the generalizations in each unit were clearly misinterpreted before instruction as well as after instruction. Moreover, these misconceptions were frequently retained for three to five months after instruction had concluded.

When one considers the per cent correct responses to a test item and the per cent incorrect responses to the same test item, the double precision scoring prodedure revealed a substantial number of test items and corresponding science generalizations which were unfamiliar or uncertain to a large proportion of the pupils who received instruction in a given unit.

4. Pupils in classes receiving instruction from science specialists did not achieve substantially higher than pupils receiving instruction from non-specialized teachers. Instruction typically involved 25 to 40 pupils per class, three to five class periods per week or approximately 10% of the pupils' week in school.

As long as the science specialist must conduct classes under the congested conditions prevelant in the Detroit Public Schools, it seems to the researcher that he will not be able to assert his talent and superior science background in teaching science to elementary school pupils. It also seems evident that the science specialist would be seriously handicapped in teaching the more subtle and complex elements relating to the process goals of science.

5. The analysis of variance of the unit tests indicated that pupils in low socio-economic communities scored significantly lower than pupils in middle and high socio-economic groups who were in the same grade group. The analysis of variance of standardized tests indicated that pupils in low socio-economic communities did not have the verbal language skills, i.e. skills in processing information from written or spoken symbols, comparable with other pupils in the same grade group.

6. Graphical analysis indicated that the normal distribution was typical of the distribution of unit achievement scores within most of the classes before instruction as well as after instruction. However, there were variations which involved log normal and skewed distributions.

Graphical analysis indicated that the instructional program enabled those pupils who were in the upper achievement level of each class to improve substantially more than pupils in the lower achievement level of a class. It was not determined whether this tendency was implicit in the units' organization, was characterized by group instruction in classes in Metropolitan Detroit, or was a product of these two elements and other influences.

7. There were high positive correlations among the double precision scores for the pre-test and post-test for the unit achievement tests. There was a moderate relationship between the standardized tests of reading comprehension, science achievement, and verbal intelligence with the unit achievement tests. For all of the standardized tests, the science achievement test had the highest positive relationship to success on the unit achievement tests.

8. The differences between raw scores upon entering instruction and concluding instruction provided estimates of the gains made by pupils in the study. Some pupils entered the instructional program with 80 to 90% of the material unknown and unfamiliar to them, as indicated by their test responses. The gains varied between a loss of 6% to gains as high as 40%. This study corroborates the wide range of individual differences which have been alluded to in other studies (82).

## E. Recommendations

1. It is recommended that a computer-based information system be established to impliment the ideas derived from the present study. It is the writer's judgment that the information processing tasks which are implicit in teaching science, as well as many other topics in the elementary school curriculum, are tremendously complicated. Substantial improvement in the efficiency and effectiveness of instruction will be achieved when instruction can be made more explicit and directed toward individual differences rather than toward group norms. It is important for the teacher to have reaction and feedback from the pupil so that the teacher can alter instruction to help the individual.

2. This study provided "bench marks" to indicate the probable success of pupils in understanding certain generalizations under existing conditions, i.e. available teachers, time, curriuclum, materials. It is recommended that a more comprehensive study be undertaken very soon to provide other "bench marks" to indicate the probable success of elementary school pupils to understand the salient ideas implicit in biology, chemistry, astronomy, and geology as well as other areas of the physical sciences. That study should follow similar procedures of documentation and consultation used in this study in order to minimize the errors and problems involved in identifying main ideas and evaluating pupils' understanding of those ideas.

3. It is recommended that independent replications of this study be carried out in other urban centers to determine the extent

to which the results derived from this study are supported or refuted by an independent source. Such replications should be conducted during the next three years. They would provide additional evidence and a basis of comparison with the accomplishments of innovations in computer-assisted instruction, program instruction, process oriented instruction, and similar innovations which are being proposed for the elementary school science program.

4. It is also recommended that further research be undertaken to make a detailed examination of the error patterns, which have been identified in this study. It would be important to know the extent to which these misconceptions or error patterns have had an impeding influence upon future learning of a particular topic.

5. Finally, it is recommended that publishers of textbooks and other educational materials for the elementary school science program be urged to collect adequate empirical evidence to document the utility of their materials.

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# Appendix A-1

## Explanation of Tables Indicating Probable Success in Understanding Generalizations

The following tables in Appendices A, B, and C provide double precision estimates of the probable success of other intermediate grade pupils in the population to understand the major generalizations which were presented to all pupils in this study.

Each major generalization is stated at the top of the table. Directly beneath each generalization is the test item generalization. The latter is derived from a test item which was written to obtain an estimate of pupils' understanding of the major generalization. The test item generalization is only one member of a large number of test item generalizations which might be subsumed under the major generalization.

Use of the tables in this appendix depends upon how much the teacher or curriculum planner knows about the pupils who are to be instructed. If the reader knows only that he has a class of sixth grade pupils, then the probability that those pupils will understand the test item generalization and its corresponding major science generalization before instruction is listed in the table at the first numeral enclosed in parentheses. The probability that these pupils will understand and retain that understanding of the test item generalization after instruction is indicated by the second numeral enclosed in parentheses. The evidence collected in this study has been directly related to pupils' understandings of the test item generalization. The inference that the pupils will undertand or not understand the major generalization is based upon this evidence.

For example, suppose that a sixth grade teacher wanted to have some idea whether or not his pupils understood the meaning of work as the term is used by scientists. The generalization (A6...Work is done when a force moves an object.) has two test item generalizations which provide some evidence of the sixth grade pupils' understanding of this generalization.

Table 31 indicates that before instruction 55% of the pupils appeared to understand that when a pencil rested upon a desk, it did not do work upon the desk. After instruction, 71% of the sixth grade pupils apparently understood this idea about work.

It would be possible to enter into lengthy discussion of the pupils' thinking and the other probability estimates in these tables. However, the present purpose is simply to illustrate the use of the two numerals enclosed in parentheses and arranged in columns in the tables of the appendices.

If the reader had reliable information about the science background, the reading proficiency, the verbal intelligence, or socio-economic background of his pupils, then a more precise estimate of their success can be offered.

For pupils in each grade level with a high, middle, or low background of science information, the second column in the tables provides estimates of their probable success in understanding each of the test item generalizations before instruction as well as after instruction.

For pupils in each grade level with high, middle, or low level of reading proficiency, the third column of figures provides estimates of their probable success in understanding each test item generalization before instruction as well as after instruction.

For pupils in each grade with a high, middle, or low level of verbal intelligence, the fourth column in the tables provides estimates that they will understand each of the test item generalizations before instruction as well as after instruction has concluded.

For pupils in each grade level who reside in low, middle or high socio-economic communities, the pairs of numbers in the fifth column provides estimates of their probable success in understanding each of the test item generalizations before instruction as well as after instruction.

Each of the sets of tables in which a major generalization is related to a test item generalization is to be interpreted in much the same fashion as all of the other tables in the Appendices.

In using these tables the reader is making certain basic assumptions which should be called to his attention. It is assumed that the reader has a group of pupils who may legitimately be considered to be members of the population of pupils defined in this study, i.e., a) These pupils are in grades four, five, or six (ages 9 years through 12 years) of public schools in Metropolitan Detroit. b) These pupils received instruction in science for approximately 120 minutes per week (about 10% of the school week). c) These pupils received instruction in groups of 25 or more pupils from competent teachers who may or may not have had a special science background.

If the reader has pupils who satisfy these conditions, then it is legitimate to use the probability estimates to project their success in understanding and retaining the generalizations about simple machines, electrical energy and heat energy. On the other hand, the reader should use extreme caution in applying these probability estimates to pupil populations who do not satisfy one or more of the conditions mentioned above. Such an extrapolation can be very misleading.

In conclusion, the reader is reminded that these are not absolute standards. They are merely estimates of probable success, "benchmarks" as it were. They are subject to fluctuation and even reversal as was the case with fourth grade pupils on electricity generalization (A2). It is hoped that they may serve as guides for curriculum planners to make judicious decisions about planning the science education of pupils in the nine year to twelve year age range. It is hoped that other researchers will find these probability estimates useful as "benchmarks" in their explorations of ways and means to improve children's understanding of generalizations in the physical sciences.

## A-4

## LIST OF GENERALIZATIONS ABOUT MACHINES WITH CORRESPONDING TEST ITEMS

### A. MECHANICAL ENERGY AND WORK

2. Mechanical energy is energy produced by a machine. (Test Item 1)

3. Energy used to do work is not lost or destroyed but its form may change. (Test Item 2)

5. A measure of work is the product of a force and the distance through which it moves. (Test Items 48, 49, 50)

6. Work is done when a force moves an object. (Test Items 3,4)

### B. SIMPLE MACHINES--LEVERS

5. In a second class lever, the load is between the effort force and the fulcrum. (Test Item 5)

6. In a third class lever, the effort is between the fulcrum and load. (Test Item 6)

7. The load arm is the distance between the fulcrum and the load. (Test Item 10)

8. The force arm is the distance between the fulcrum and the effort force. (Test Item 11)

9. Pliers, bottle openers, brooms, baseball bats, and shovels are examples of the lever. (Test Item 17)

10. When the force arm is longer than the load arm, a small force moves a heavy load. (Test Items 12, 15, 18, 19)

11. When the force arm is longer than the load arm, the effort force is moved a greater distance than the load. (Test Item 14)

12. When the force arm is as long as the load arm, no mechanical advantage is gained. (Test Items 8, 13, 16)

13. When the load arm is longer than the force arm, the load travels farther than the effort force. (Test Item 9)

15. When the load arm is longer than the force arm, the effort must be greater than the load in order to move it. (Test Item 7)

## C. SIMPLE MACHINES--PULLEYS

1. A single fixed pulley needs a force larger than the load to be lifted. (Test Items 20, 21, 22)

4. Elevators, hoists, steam shovels, and the painters' scaffolds use pulleys. (Test Item 24)

5. A load is raised a short distance by a movable pulley, but the lifting force must travel a long distance. (Test Items 23, 25)

7. The number of strands in a pulley system indicates the gain in lifting force. (Test Item 26)

## D. SIMPLE MACHINES--WHEEL AND AXLE

1. When a wheel and axle is turned, a point on the rim of the wheel travels farther than does a point on the rim of the axle. (Test Items 27, 28, 33)

2. When a wheel and axle is turned, the edge of the wheel travels faster than the edge of the axle. (Test Items 29, 30)

3. A small force on the wheel will move a heavy load on the axle. (Test Item 31)

4. As the wheel becomes larger, it takes less force on the wheel to move the same load on the axle. (Test Items 32, 34)

## E. SIMPLE MACHINES--INCLINED PLANE

1. An inclined plane is another kind of simple machine. (Test Item 35)

3. Wedges and screws are special forms of the inclined plane. (Test Item 36, 37)

## F. FRICTION

1. Friction is a force resisting motion between two surfaces in contact. (Test Items 38, 39, 40)

2. Friction produces heat. (Test Item 41)

3. There is some friction in every machine when it is being used. (Test Item 42)

5. Sliding friction is important in writing, walking, running. (Test Item 43)

6. Fluid friction is important to objects traveling through air, water, or other fluids. (Test Items 44, 46)

7. Rolling friction is important to the use of automobiles, roller skates, bicycles. (Test Items 45, 47)

Table 24

## NUMBER OF PUPILS USED IN EACH GRADE GROUP AND WITH TEST VARIABLES TO ESTABLISH PROBABILITY ESTIMATES OF SUCCESS FOR GENERALIZATIONS ABOUT MACHINES

A-7

| | | Science Bkgd. | Read. Comp. | Intel. Quot. | Soc-Econ. |
|---|---|---|---|---|---|
| | M12 M23 | M12 M23 | M12 M23 | M12 M23 | M12 M23 |
| | | High (121, 115) | High ( 65, 56) | High (132, 122) | High (121, 130) |
| Grade 6 | (449, 403) | Mid (186, 163) | Mid (214, 195) | Mid (227, 192) | Mid (267, 235) |
| | | Low ( 99, 88) | Low (147, 129) | Low ( 43, 34) | Low ( 63, 40) |
| | M12 M23 | M12 M23 | M12 M23 | M12 M23 | M12 M23 |
| | | High (107, 78) | High ( 42, 36) | High (115, 101) | High (100, 102) |
| Grade 5 | (352, 296) | Mid (145, 130) | Mid (135, 118) | Mid (147, 131) | Mid (164, 146) |
| | | Low ( 75, 48) | Low (131, 91) | Low ( 40, 22) | Low ( 90, 50) |
| | M12 M23 | M12 M23 | M12 M23 | M12 M23 | M12 M23 |
| | | High ( --, --) | High ( --, --) | High ( 23, 27) | High ( 19, 21) |
| Grade 4 | (132, 122) | Mid ( 83, 82) | Mid ( 71, 69) | Mid ( 53, 57) | Mid ( 79, 79) |
| | | Low ( --, --) | Low ( 50, 37) | Low ( --, --) | Low ( 36, 24) |

In grade 6, there were 449 pupils used to establish probability estimates for each generalization on the double precision test (M12) and 403 pupils were used for the (M23) test. Probability estimates are not reported for samples of 15 pupils or less.

Table 25 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization:** A2. Mechanical energy is energy produced by a machine.

**Test Item Generalization:** 1. If there is an automobile, then it has mechanical energy for use.

A-8

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (56, 53) | High (56, 62) | High (62, 64) | High (52, 55) | High (46, 42) |
| | Mid. (52, 48) | Mid. (53, 54) | Mid. (52, 51) | Mid. (55, 58) |
| | Low (62, 50) | Low (58, 50) | Low (53, 41) | Low (73, 60) |
| 5 (56, 56) | High (55, 63) | High (67, 56) | High (54, 67) | High (46, 59) |
| | Mid. (55, 55) | Mid. (57, 58) | Mid. (58, 53) | Mid. (56, 55) |
| | Low (53, 48) | Low (51, 54) | Low (58, 45) | Low (65, 52) |
| 4 (57, 54) | High (--, --) | High (--, --) | High (70, 70) | High (37, 33) |
| | Mid. (54, 55) | Mid. (58, 57) | Mid. (51, 44) | Mid. (61, 58) |
| | Low (--, --) | Low (52, 51) | Low (--, --) | Low (56, 54) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 26 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: A3. Energy used to do work is not lost or destroyed but its form may change.

Test Item Generalization: 2. If a boy runs and uses energy, then something else has that energy now.

A-9

| Grade Level | Information Known About Pupils | | | |
|---|---|---|---|---|
| | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (04, 08) | High (03, 11) | High (03, 06) | High (03, 10) |
| 6 (03, 05) | Mid. (02, 04) | Mid. (02, 05) | Mid. (04, 03) | Mid. (03, 03) |
| | Low (05, 06) | Low (05, 05) | Low (05, 06) | Low (06, 05) |
| | High (02, 03) | High (07, 03) | High (03, 02) | High (02, 01) |
| 5 (02, 03) | Mid. (01, 01) | Mid. (01, 03) | Mid. (01, 03) | Mid. (02, 03) |
| | Low (03, 04) | Low (02, 02) | Low (08, 01) | Low (03, 04) |
| | High (--, --) | High (--, --) | High (13, 07) | High (05, 10) |
| 4 (04, 10) | Mid. (05, 12) | Mid. (04, 07) | Mid. (02, 14) | Mid. (05, 08) |
| | Low (--, --) | Low (04, 16) | Low (--, --) | Low (01, 17) |

*First numeral in parentheses indicates probable success before instruction (success on M12). Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 27 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: A5. A measure of work is the product of a force and the distance through which it moves.

Test Item Generalization: 48. If the 100 pound stick man runs five feet, then 500 units of work are done.

A-10

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (10, 18) | High (12, 29) | High (11, 32) | High (14, 28) | High (12, 30) |
|  | Mid. (08, 16) | Mid. (10, 20) | Mid. (09, 14) | Mid. (11, 14) |
|  | Low (11, 09) | Low (12, 09) | Low (07, 06) | Low (03, 01) |
| 5 (08, 09) | High (07, 10) | High (07, 17) | High (09, 14) | High (06, 07) |
|  | Mid. (07, 08) | Mid. (06, 08) | Mid. (06, 08) | Mid. (10, 10) |
|  | Low (12, 06) | Low (08, 07) | Low (15, 01) | Low (08, 14) |
| 4 (08, 11) | High (--, --) | High (--, --) | High (13, 19) | High (05, 05) |
|  | Mid. (05, 07) | Mid. (04, 09) | Mid. (04, 07) | Mid. (05, 13) |
|  | Low (--, --) | Low (10, 11) | Low (--, --) | Low (14, 08) |

*First numeral in parentheses indicates probable success before instruction (success on M12). Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 28 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: A5. A measure of work is the product of a force and the distance through which it moves.

Test Item Generalization: 49. If 2 pounds of snow are moved 6 feet, then 12 units of work are done.

A-11

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| | High (55, 70) | High (48, 73) | High (47, 67) | High (39, 61) |
| 6 (38, 50) | Mid. (35, 51) | Mid. (42, 57) | Mid. (33, 45) | Mid. (40, 49) |
| | Low (26, 28) | Low (28, 32) | Low (16, 18) | Low (27, 25) |
| | High (34, 59) | High (36, 47) | High (38, 53) | High (26, 41) |
| 5 (25, 40) | Mid. (24, 38) | Mid. (27, 43) | Mid. (18, 38) | Mid. (27, 42) |
| | Low (15, 19) | Low (20, 29) | Low (15, 23) | Low (20, 28) |
| | High (--, --) | High (--, --) | High (22, 33) | High (16, 33) |
| 4 (20, 26) | Mid. (17, 24) | Mid. (15, 30) | Mid. (26, 30) | Mid. (22, 29) |
| | Low (--, --) | Low (26, 16) | Low (--, --) | Low (19, 08) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 29 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: A5. A measure of work is the product of a force and the distance through which it moves.

Test Item Generalization: 50. If 3 boys move 6 feet, then more information is needed to determine how much work was done.

A-12

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| 6 (13, 21) | High (18, 30) | High (18, 30) | High (26, 39) | High (14, 28) |
| | Mid. (11, 20) | Mid. (15, 25) | Mid. (10, 16) | Mid. (14, 18) |
| | Low (12, 11) | Low (09, 13) | Low (16, 09) | Low (10, 18) |
| 5 (08, 15) | High (13, 21) | High (17, 17) | High (11, 20) | High (11, 23) |
| | Mid. (08, 14) | Mid. (08, 12) | Mid. (08, 11) | Mid. (10, 10) |
| | Low (03, 10) | Low (05, 11) | Low (01, 09) | Low (02, 10) |
| 4 (08, 09) | High (--, --) | High (--, --) | High (09, 15) | High (05, 10) |
| | Mid. (08, 07) | Mid. (07, 10) | Mid. (04, 05) | Mid. (09, 10) |
| | Low (--, --) | Low (08, 08) | Low (--, --) | Low (06, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 30 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: A6. Work is done when a force moves an object.

Test Item Generalization: 3. If a man leans against a tree, then no work is done by the man upon the tree.

A-13

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| | High (55, 66) | High (58, 68) | High (45, 69) | High (35, 65) |
| 6 (39, 55) | Mid. (33, 55) | Mid. (39, 57) | Mid. (35, 47) | Mid. (42, 51) |
| | Low (30, 39) | Low (30, 44) | Low (23, 35) | Low (32, 40) |
| | High (41, 59) | High (43, 69) | High (39, 61) | High (26, 55) |
| 5 (33, 50) | Mid. (36, 53) | Mid. (41, 48) | Mid. (35, 48) | Mid. (40, 47) |
| | Low (21, 25) | Low (24, 43) | Low (13, 18) | Low (29, 50) |
| | High (--, --) | High (--, --) | High (26, 48) | High (11, 33) |
| 4 (20, 38) | Mid. (19, 43) | Mid. (17, 42) | Mid. (21, 40) | Mid. (24, 41) |
| | Low (--, --) | Low (18, 24) | Low (--, --) | Low (14, 29) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 31 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization**: A6. Work is done when a force moves an object.

**Test Item Generalization**: 4. If a pencil rests upon a desk, then no work is done by the pencil upon the desk.

A-14

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| **Grade Level** | **Science Bkgd.** | **Reading Comp.** | **Intel. Quotient** | **Soc-Econ. Level** |
| | High (64, 83) | High (68, 86) | High (63, 81) | High (47, 72) |
| 6 (55, 71) | Mid. (54, 77) | Mid. (54, 75) | Mid. (49, 67) | Mid. (58, 74) |
| | Low (42, 50) | Low (48, 57) | Low (42, 53) | Low (52, 50) |
| | High (70, 73) | High (74, 89) | High (65, 80) | High (55, 70) |
| 5 (55, 68) | Mid. (53, 69) | Mid. (55, 67) | Mid. (54, 67) | Mid. (57, 66) |
| | Low (43, 48) | Low (47, 57) | Low (48, 41) | Low (51, 68) |
| | High (--, --) | High (--, --) | High (48, 74) | High (26, 48) |
| 4 (42, 56) | Mid. (40, 56) | Mid. (41, 62) | Mid. (36, 51) | Mid. (44, 59) |
| | Low (--, --) | Low (36, 46) | Low (--, --) | Low (42, 46) |

*First numeral in parentheses indicates probable success before instruction (success on M12). Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 32 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: B5. In a second class lever, the load is between the effort force and the fulcrum.

Test Item Generalization: 5. If there is a second class lever, then the load is between the fulcrum and the effort force.

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (03, 17) | High (02, 29) | High (06, 13) | High (11, 17) |
| 6 (04, 10) | Mid. (06, 09) | Mid. (06, 07) | Mid. (04, 06) | Mid. (03, 09) |
| | Low (03, 05) | Low (03, 08) | Low (02, 03) | Low (01, 01) |
| | High (06, 13) | High (12, 19) | High (09, 16) | High (04, 12) |
| 5 (06, 07) | Mid. (04, 05) | Mid. (05, 06) | Mid. (04, 03) | Mid. (06, 05) |
| | Low (05, 02) | Low (05, 04) | Low (05, 05) | Low (07, 06) |
| | High (--, --) | High (--, --) | High (04, 04) | High (11, 01) |
| 4 (04, 02) | Mid. (02, 01) | Mid. (03, 01) | Mid. (04, 01) | Mid. (04, 03) |
| | Low (--, --) | Low (04, 01) | Low (--, --) | Low (01, 01) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

## Table 33 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: B6. In a third class lever, the effort is between the fulcrum and load.

Test Item Generalization: 6. If there is a third class lever, then the effort force is between the fulcrum and the load.

A-16

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (05, 14) | High (05, 22) | High (02, 14) | High (05, 25) | High (05, 19) |
| | Mid. (05, 12) | Mid. (04, 16) | Mid. (05, 08) | Mid. (05, 11) |
| | Low (07, 09) | Low (09, 10) | Low (07, 03) | Low (06, 08) |
| 5 (05, 07) | High (04, 12) | High (05, 14) | High (03, 13) | High (04, 08) |
| | Mid. (05, 04) | Mid. (07, 05) | Mid. (05, 03) | Mid. (04, 08) |
| | Low (05, 04) | Low (04, 05) | Low (05, 05) | Low (08, 04) |
| 4 (02, 07) | High (--, --) | High (--, --) | High (01, 15) | High (01, 10) |
| | Mid. (04, 05) | Mid. (04, 06) | Mid. (04, 04) | Mid. (03, 06) |
| | Low (--, --) | Low (01, 05) | Low (--, --) | Low (03, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 34 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization**: **B7. The load arm is the distance between the fulcrum and the load.**

**Test Item Generalization**: 10. **If the load of a lever is farther from the fulcrum than the force, then the load arm is longer than the force arm.**

A-17

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (08, 18) | High (14, 23) | High (11, 18) | High (11, 25) | High (05, 24) |
| | Mid. (06, 18) | Mid. (09, 19) | Mid. (05, 13) | Mid. (10, 16) |
| | Low (01, 08) | Low (03, 12) | Low (05, 06) | Low (03, 08) |
| 5 (05, 10) | High (07, 13) | High (07, 25) | High (04, 14) | High (06, 10) |
| | Mid. (06, 08) | Mid. (07, 09) | Mid. (08, 11) | Mid. (07, 13) |
| | Low (03, 08) | Low (03, 07) | Low (01, 05) | Low (02, 04) |
| 4 (06, 09) | High (--, --) | High (--, --) | High (09, 15) | High (05, 14) |
| | Mid. (04, 10) | Mid. (07, 09) | Mid. (08, 05) | Mid. (06, 09) |
| | Low (--, --) | Low (02, 05) | Low (--, --) | Low (06, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 35 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization:** B8. The force arm is the distance between the fulcrum and the effort force.

**Test Item Generalization:** 11. If the force of a lever is farther from the fulcrum than the load, then the force arm is longer than the load arm.

A-18

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (12, 17) | High (17, 23) | High (14, 39) | High (16, 23) | High (09, 22) |
| | Mid. (11, 16) | Mid. (14, 15) | Mid. (12, 15) | Mid. (15, 16) |
| | Low (08, 11) | Low (10, 11) | Low (02, 09) | Low (05, 08) |
| 5 (11, 14) | High (15, 19) | High (17, 36) | High (15, 22) | High (14, 20) |
| | Mid. (09, 12) | Mid. (13, 08) | Mid. (10, 08) | Mid. (10, 09) |
| | Low (13, 08) | Low (09, 12) | Low (18, 01) | Low (11, 16) |
| 4 (09, 07) | High (--, --) | High (--, --) | High (04, 15) | High (01, 05) |
| | Mid. (10, 06) | Mid. (06, 06) | Mid. (08, 05) | Mid. (09, 09) |
| | Low (--, --) | Low (12, 03) | Low (--, --) | Low (14, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12). Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 36 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: B9. Pliers, bottle openers, brooms, baseball bats, and shovels are examples of the lever.

Test Item Generalization: 17. If it is a shovel or crowbar or hammer, then it may be used as a lever.

A-19

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (28, 48) | High (42, 70) | High (49, 71) | High (45, 61) | High (36, 55) |
| | Mid. (25, 44) | Mid. (32, 51) | Mid. (20, 43) | Mid. (28, 47) |
| | Low (10, 32) | Low (11, 33) | Low (09, 32) | Low (11, 30) |
| 5 (14, 34) | High (28, 42) | High (26, 36) | High (25, 50) | High (24, 37) |
| | Mid. (10, 30) | Mid. (10, 31) | Mid. (10, 27) | Mid. (12, 34) |
| | Low (03, 15) | Low (08, 26) | Low (03, 14) | Low (07, 24) |
| 4 (10, 25) | High (--, --) | High (--, --) | High (13, 37) | High (11, 33) |
| | Mid. (12, 22) | Mid. (10, 26) | Mid. (11, 23) | Mid. (14, 28) |
| | Low (--, --) | Low (08, 19) | Low (--, --) | Low (01, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 37 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: B10. When the force arm is longer than the load arm, a small force moves a heavy load.

Test Item Generalization: 12. If the force arm is larger than the load arm and the force is greater than the load, and the force has moved as far as it can, then the load won't be moved. A-20

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (11, 22) | High (17, 23) | High (11, 17) | High (06, 14) |
| 6 (10, 14) | Mid. (10, 12) | Mid. (08, 13) | Mid. (08, 14) | Mid. (11, 16) |
| | Low (08, 09) | Low (08, 12) | Low (07, 06) | Low (11, 03) |
| | High (17, 15) | High (12, 17) | High (09, 14) | High (09, 16) |
| 5 (07, 10) | Mid. (06, 08) | Mid. (06, 11) | Mid. (07, 11) | Mid. (07, 10) |
| | Low (08, 06) | Low (08, 08) | Low (05, 09) | Low (07, 02) |
| | High (--, --) | High (--, --) | High (09, 07) | High (01, 05) |
| 4 (03, 07) | Mid. (04, 10) | Mid. (03, 07) | Mid. (02, 09) | Mid. (04, 09) |
| | Low (--, --) | Low (01, 03) | Low (--, --) | Low (03, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 38 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: B10. When the load arm is longer than the force arm, the load travels faster than the effort force.

Test Item Generalization: 15. If the load arm of a lever is longer than the force arm, then the load travels faster than the force.

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| | High (14, 18) | High (12, 14) | High (16, 16) | High (16, 17) |
| 6 (13, 15) | Mid. (14, 16) | Mid. (14, 17) | Mid. (13, 14) | Mid. (12, 16) |
| | Low (10, 10) | Low (12, 11) | Low (07, 03) | Low (14, 05) |
| | High (14, 17) | High (10, 11) | High (16, 17) | High (09, 16) |
| 5 (12, 13) | Mid. (14, 14) | Mid. (16, 14) | Mid. (12, 13) | Mid. (15, 12) |
| | Low (05, 04) | Low (09, 05) | Low (05, 05) | Low (09, 10) |
| | High (--, --) | High (--, --) | High (09, 11) | High (01, 19) |
| 4 (05, 11) | Mid. (04, 12) | Mid. (06, 12) | Mid. (04, 11) | Mid. (08, 10) |
| | Low (--, --) | Low (04, 08) | Low (--, --) | Low (03, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 39 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: B10. When the force arm is longer than the load arm, a small force moves a heavy load.

Test Item Generalization: 18. If the force arm of a lever is made longer, then the load is easier to move.

A-22

| Grade Level | Information Known About Pupils | | | |
|---|---|---|---|---|
| | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (06, 11) | High (08, 18) | High (08, 16) | High (07, 14) |
| 6 (07, 13) | Mid. (08, 18) | Mid. (07, 13) | Mid. (06, 12) | Mid. (07, 14) |
| | Low (05, 09) | Low (06, 10) | Low (05, 03) | Low (06, 05) |
| | High (05, 09) | High (07, 14) | High (06, 11) | High (08, 15) |
| 5 (05, 11) | Mid. (06, 15) | Mid. (05, 11) | Mid. (06, 13) | Mid. (04, 10) |
| | Low (04, 08) | Low (04, 10) | Low (01, 01) | Low (06, 06) |
| | High (--, --) | High (--, --) | High (04, 15) | High (01, 10) |
| 4 (02, 09) | Mid. (02, 09) | Mid. (01, 12) | Mid. (02, 09) | Mid. (04, 11) |
| | Low (--, --) | Low (02, 03) | Low (--, --) | Low (01, 01) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 40 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: B10. When the force arm is longer than the load arm, a small force moves a heavy load.

Test Item Generalization: 19. If a first class lever is used to move a load, then the smallest force is used when the fulcrum is placed close to the load.

A-23

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (06, 15) | High (08, 18) | High (08, 15) | High (10, 12) |
| 6 (07, 09) | Mid. (08, 08) | Mid. (08, 10) | Mid. (06, 04) | Mid. (06, 08) |
| | Low (07, 03) | Low (05, 04) | Low (02, 01) | Low (05, 03) |
| | High (04, 14) | High (01, 11) | High (03, 11) | High (03, 13) |
| 5 (03, 07) | Mid. (03, 08) | Mid. (02, 07) | Mid. (01, 06) | Mid. (03, 05) |
| | Low (01, 02) | Low (02, 07) | Low (03, 05) | Low (02, 02) |
| | High (--, --) | High (--, --) | High (01, 04) | High (01, 05) |
| 4 (03, 04) | Mid. (04, 05) | Mid. (01, 01) | Mid. (04, 04) | Mid. (03, 04) |
| | Low (--, --) | Low (06, 08) | Low (--, --) | Low (06, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 41 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization**: B11. When the force arm is longer than the load arm, the effort fewce is moved a greater distance than the load.

**Test Item Generalization**: 14. If the force arm of a lever is longer than the load arm, then the force travels farther than the load.

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (14, 28) | High (12, 27) | High (12, 26) | High (17, 28) |
| 6 (12, 20) | Mid. (11, 20) | Mid. (13, 24) | Mid. (12, 17) | Mid. (10, 19) |
| | Low (08, 07) | Low (11, 13) | Low (05, 03) | Low (10, 03) |
| | High (15, 24) | High (12, 22) | High (14, 23) | High (11, 25) |
| 5 (09, 17) | Mid. (05, 16) | Mid. (07, 24) | Mid. (08, 15) | Mid. (09, 15) |
| | Low (07, 06) | Low (06, 03) | Low (05, 09) | Low (06, 04) |
| | High (--, --) | High (--, --) | High (01, 11) | High (01, 10) |
| 4 (02, 13) | Mid. (02, 13) | Mid. (01, 20) | Mid. (01, 16) | Mid. (01, 18) |
| | Low (--, --) | Low (02, 03) | Low (--, --) | Low (03, 01) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 42 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: B12. When the force arm is as long as the load arm, no mechanical advantage is gained.

Test Item Generalization: 8. If the load arm and the force arm of a lever are equal and the load is equal to the force, then no work is done with the lever.

A-25

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (19, 34) | High (34, 51) | High (28, 41) | High (26, 48) | High (24, 40) |
| | Mid. (14, 29) | Mid. (20, 37) | Mid. (14, 28) | Mid. (19, 34) |
| | Low (10, 19) | Low (14, 24) | Low (09, 09) | Low (06, 10) |
| 5 (12, 26) | High (27, 37) | High (12, 19) | High (20, 35) | High (18, 27) |
| | Mid. (08, 25) | Mid. (14, 31) | Mid. (10, 23) | Mid. (10, 25) |
| | Low (04, 15) | Low (11, 21) | Low (05, 18) | Low (09, 26) |
| 4 (09, 18) | High (--, --) | High (--, --) | High (30, 33) | High (05, 19) |
| | Mid. (06, 17) | Mid. (13, 23) | Mid. (02, 14) | Mid. (11, 18) |
| | Low (--, --) | Low (02, 08) | Low (--, --) | Low (06, 17) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 43 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization**: B12. When the force arm is as long as the load arm, no mechanical advantage is gained.

**Test Item Generalization**: 13. If the load arm of a lever is as long as the force arm, then the load and force travel at the same speed.

A-26

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (30, 35) | High (32, 32) | High (25, 27) | High (22, 32) |
| 6 (22, 31) | Mid. (23, 33) | Mid. (24, 29) | Mid. (19, 32) | Mid. (24, 31) |
| | Low (14, 30) | Low (14, 35) | Low (14, 29) | Low (11, 25) |
| | High (18, 27) | High (14, 31) | High (16, 24) | High (15, 26) |
| 5 (15, 22) | Mid. (15, 25) | Mid. (18, 24) | Mid. (17, 24) | Mid. (16, 24) |
| | Low (11, 17) | Low (15, 19) | Low (10, 14) | Low (11, 08) |
| | High (--, --) | High (--, --) | High (26, 26) | High (21, 29) |
| 4 (10, 21) | Mid. (07, 23) | Mid. (08, 23) | Mid. (09, 21) | Mid. (08, 16) |
| | Low (--, --) | Low (08, 11) | Low (--, --) | Low (08, 29) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 44 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: B12. When the force arm is as long as the load arm, no mechanical advantage is gained.

Test Item Generalization: 16. If the load arm of a lever is as long as the force arm, then the load and force travel the same distance.

A-27

| Grade Level | Information Known About Pupils | | | |
|---|---|---|---|---|
| | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (34, 42) | High (45, 48) | High (42, 52) | High (43, 44) | High (34, 41) |
| | Mid. (35, 45) | Mid. (36, 41) | Mid. (27, 42) | Mid. (35, 43) |
| | Low (21, 34) | Low (25, 39) | Low (33, 29) | Low (29, 35) |
| 5 (25, 40) | High (37, 42) | High (31, 47) | High (33, 46) | High (28, 40) |
| | Mid. (21, 43) | Mid. (25, 40) | Mid. (22, 41) | Mid. (24, 40) |
| | Low (16, 27) | Low (22, 36) | Low (18, 32) | Low (21, 34) |
| 4 (16, 23) | High (--, --) | High (--, --) | High (09, 19) | High (21, 29) |
| | Mid. (17, 24) | Mid. (20, 25) | Mid. (23, 26) | Mid. (18, 22) |
| | Low (--, --) | Low (08, 22) | Low (--, --) | Low (08, 21) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 45 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: B13. When the load arm is longer than the force arm, the load travels farther than the effort force.

Test Item Generalization: 9. If the load arm of a lever is longer than the force arm, then the load travels farther than the force.

A-28

| Grade Level | Information Known About Pupils | | | |
|---|---|---|---|---|
| | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (28, 45) | High (22, 45) | High (17, 34) | High (19, 27) |
| 6 (24, 29) | Mid. (22, 26) | Mid. (21, 31) | Mid. (25, 24) | Mid. (23, 31) |
| | Low (21, 14) | Low (26, 16) | Low (30, 18) | Low (33, 18) |
| | High (19, 31) | High (21, 28) | High (17, 34) | High (17, 24) |
| 5 (13, 22) | Mid. (12, 19) | Mid. (08, 15) | Mid. (11, 16) | Mid. (11, 18) |
| | Low (07, 13) | Low (13, 18) | Low (10, 14) | Low (11, 22) |
| | High (--, --) | High (--, --) | High (17, 11) | High (37, 24) |
| 4 (18, 11) | Mid. (19, 10) | Mid. (14, 12) | Mid. (23, 11) | Mid. (10, 10) |
| | Low (--, --) | Low (20, 05) | Low (--, --) | Low (25, 01) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 46 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization:** B15. When the load arm is longer than the force arm, the effort must be greater than the load in order to move it.

**Test Item Generalization:** 7. If the force arm of the lever is shorter than the load arm, then a large force is needed to move the load.

A-29

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (15, 31) | High (30, 49) | High (23, 48) | High (26, 44) | High (20, 36) |
| | Mid. (12, 28) | Mid. (18, 34) | Mid. (09, 28) | Mid. (16, 31) |
| | Low (05, 14) | Low (07, 19) | Low (05, 09) | Low (03, 10) |
| 5 (10, 24) | High (14, 28) | High (17, 28) | High (13, 34) | High (18, 28) |
| | Mid. (09, 25) | Mid. (08, 28) | Mid. (08, 22) | Mid. (06, 23) |
| | Low (04, 19) | Low (06, 15) | Low (01, 14) | Low (07, 20) |
| 4 (14, 20) | High (--, --) | High (--, --) | High (22, 33) | High (11, 29) |
| | Mid. (07, 17) | Mid. (11, 19) | Mid. (13, 19) | Mid. (14, 20) |
| | Low (--, --) | Low (14, 16) | Low (--, --) | Low (14, 13) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 47 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization**: C1. A single fixed pulley needs a force larger than the load to be lifted.

**Test Item Generalization**: 20. If a one-strand pulley is used, the load travels the same distance as the force.

A-30

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (05, 06) | High (03, 09) | High (03, 05) | High (03, 07) | High (02, 07) |
|  | Mid. (04, 06) | Mid. (04, 07) | Mid. (06, 06) | Mid. (06, 07) |
|  | Low (08, 05) | Low (07, 05) | Low (07, 03) | Low (06, 01) |
| 5 (04, 03) | High (05, 01) | High (02, 03) | High (03, 01) | High (02, 01) |
|  | Mid. (02, 02) | Mid. (01, 02) | Mid. (03, 03) | Mid. (03, 03) |
|  | Low (05, 02) | Low (05, 03) | Low (08, 01) | Low (07, 04) |
| 4 (04, 03) | High (--, --) | High (--, --) | High (04, 07) | High (01, 10) |
|  | Mid. (05, 04) | Mid. (03, 04) | Mid. (02, 04) | Mid. (05, 03) |
|  | Low (--, --) | Low (04, 03) | Low (--, --) | Low (03, 01) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 48 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization:** C1. A single fixed pulley needs a force larger than the load to be lifted.

**Test Item Generalization:** 21. If a one-strand pulley is used, then a load is moved only by a larger force.

A-31

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (35, 43) | High (53, 63) | High (51, 61) | High (45, 60) | High (35, 45) |
|  | Mid. (30, 39) | Mid. (37, 48) | Mid. (28, 38) | Mid. (39, 46) |
|  | Low (18, 22) | Low (23, 29) | Low (14, 12) | Low (17, 20) |
| 5 (26, 38) | High (40, 50) | High (43, 61) | High (39, 50) | High (27, 43) |
|  | Mid. (26, 37) | Mid. (29, 37) | Mid. (23, 35) | Mid. (29, 36) |
|  | Low (09, 13) | Low (17, 27) | Low (05, 18) | Low (21, 30) |
| 4 (16, 20) | High (--, --) | High (--, --) | High (35, 30) | High (21, 24) |
|  | Mid. (12, 17) | Mid. (14, 20) | Mid. (11, 18) | Mid. (19, 22) |
|  | Low (--, --) | Low (10, 11) | Low (--, --) | Low (06, 08) |

*First numeral in parentheses indicates probable success before instruction (success on M12). Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 49 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: C1. A single fixed pulley needs a force larger than the load to be lifted.

Test Item Generalization: 22. If a one-strand pulley is used, then a load is moved only by a larger force.

A-32

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (61, 57) | High (62, 57) | High (51, 49) | High (39, 42) |
| 6 (42, 46) | Mid. (38, 44) | Mid. (41, 47) | Mid. (38, 46) | Mid. (44, 47) |
| | Low (28, 34) | Low (36, 42) | Low (23, 32) | Low (35, 46) |
| | High (50, 51) | High (57, 56) | High (54, 55) | High (41, 48) |
| 5 (40, 45) | Mid. (39, 42) | Mid. (47, 47) | Mid. (37, 44) | Mid. (46, 45) |
| | Low (24, 40) | Low (27, 37) | Low (23, 27) | Low (27, 38) |
| | High (--, --) | High (--, --) | High (39, 41) | High (47, 52) |
| 4 (25, 32) | Mid. (24, 30) | Mid. (24, 33) | Mid. (25, 35) | Mid. (19, 32) |
| | Low (--, --) | Low (22, 27) | Low (--, --) | Low (25, 13) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 50 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: C4. Elevators, hoists, steam shovels, and the painters' scaffolds use pulleys.

Test Item Generalization: 24. If it is a flagpole or steam shovel or elevator, then it uses a pulley.

A-33

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (87, 86) | High (86, 80) | High (87, 88) | High (80, 81) |
| 6 (76, 81) | Mid. (78, 83) | Mid. (80, 85) | Mid. (73, 78) | Mid. (76, 81) |
| | Low (62, 70) | Low (64, 74) | Low (51, 65) | Low (65, 73) |
| | High (85, 82) | High (86, 81) | High (84, 82) | High (75, 71) |
| 5 (66, 74) | Mid. (63, 75) | Mid. (71, 81) | Mid. (61, 76) | Mid. (66, 77) |
| | Low (43, 50) | Low (53, 64) | Low (43, 50) | Low (52, 68) |
| | High (--, --) | High (--, --) | High (78, 81) | High (68, 81) |
| 4 (54, 67) | Mid. (53, 68) | Mid. (63, 71) | Mid. (57, 72) | Mid. (60, 66) |
| | Low (--, --) | Low (32, 54) | Low (--, --) | Low (31, 54) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 51 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

__Generalization__: C5. A load is raised a short distance by a movable pulley, but the lifting force must travel a long distance.

__Test Item Generalization__: 23. If a two-strand pulley is used, then the moving force travels farther than the load.

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (04, 06) | High (01, 06) | High (02, 07) | High (04, 02) | High (05, 03) |
| | Mid. (04, 05) | Mid. (04, 05) | Mid. (03, 04) | Mid. (03, 06) |
| | Low (09, 08) | Low (05, 04) | Low (07, 18) | Low (06, 15) |
| 5 (04, 03) | High (02, 05) | High (01, 03) | High (02, 04) | High (03, 02) |
| | Mid. (07, 02) | Mid. (03, 03) | Mid. (05, 03) | Mid. (04, 03) |
| | Low (03, 02) | Low (08, 02) | Low (03, 01) | Low (06, 02) |
| 4 (01, 02) | High (--, --) | High (--, --) | High (01, 04) | High (01, 01) |
| | Mid. (01, 02) | Mid. (01, 01) | Mid. (02, 04) | Mid. (01, 04) |
| | Low (--, --) | Low (01, 01) | Low (--, --) | Low (01, 01) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 52 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: C5. A load is raised a short distance by a movable pulley, but the lifting force must travel a long distance.

Test Item Generalization: 25. If a load is moved two feet by a movable pulley, then the moving force travels at least four feet.

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (07, 15) | High (17, 20) | High (10, 17) | High (08, 16) |
| 6 (10, 12) | Mid. (08, 15) | Mid. (06, 15) | Mid. (08, 09) | Mid. (08, 11) |
| | Low (16, 03) | Low (12, 05) | Low (21, 06) | Low (17, 03) |
| | High (10, 13) | High (07, 06) | High (07, 13) | High (09, 14) |
| 5 (09, 10) | Mid. (04, 12) | Mid. (07, 12) | Mid. (07, 11) | Mid. (07, 06) |
| | Low (13, 06) | Low (10, 12) | Low (15, 09) | Low (12, 16) |
| | High (--, --) | High (--, --) | High (01, 19) | High (01, 10) |
| 4 (06, 11) | Mid. (07, 06) | Mid. (03, 09) | Mid. (02, 04) | Mid. (05, 09) |
| | Low (--, --) | Low (12, 11) | Low (--, --) | Low (11, 17) |

*First numeral in parentheses indicates probable success before instruction (success on M12). Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 53 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: C7. The number of strands in a pulley system indicates the gain in lifting force.

Test Item Generalization: 26. If a pulley is used to move a load, then the pulley with the most strands from the load uses the least force.

A-36

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (21, 40) | High (29, 57) | High (28, 52) | High (26, 57) | High (26, 45) |
| | Mid. (18, 38) | Mid. (20, 43) | Mid. (20, 33) | Mid. (21, 41) |
| | Low (14, 18) | Low (20, 30) | Low (14, 15) | Low (16, 13) |
| 5 (14, 32) | High (21, 49) | High (29, 44) | High (17, 47) | High (13, 39) |
| | Mid. (14, 29) | Mid. (16, 35) | Mid. (13, 27) | Mid. (20, 32) |
| | Low (05, 06) | Low (08, 20) | Low (08, 14) | Low (06, 16) |
| 4 (14, 22) | High (--, --) | High (--, --) | High (22, 37) | High (16, 29) |
| | Mid. (14, 20) | Mid. (18, 22) | Mid. (15, 19) | Mid. (18, 23) |
| | Low (--, --) | Low (02, 14) | Low (--, --) | Low (06, 13) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 54 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: D1. When a wheel and axle is turned, a point on the rim of the wheel travels farther than does a point on the rim of the axle.

Test Item Generalization: 27. If a large and small wheel make one complete turn, then the large wheel travels farther.

A-37

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (35, 47) | High (34, 45) | High (32, 40) | High (21, 32) |
| 6 (24, 34) | Mid. (23, 34) | Mid. (27, 42) | Mid. (23, 36) | Mid. (30, 40) |
| | Low (16, 20) | Low (18, 19) | Low (16, 15) | Low (08, 05) |
| | High (26, 42) | High (36, 39) | High (28, 35) | High (28, 30) |
| 5 (18, 25) | Mid. (17, 17) | Mid. (16, 25) | Mid. (15, 23) | Mid. (15, 24) |
| | Low (07, 19) | Low (11, 16) | Low (05, 18) | Low (10, 16) |
| | High (--, --) | High (--, --) | High (17, 15) | High (21, 19) |
| 4 (12, 11) | Mid. (11, 09) | Mid. (11, 12) | Mid. (09, 09) | Mid. (13, 09) |
| | Low (--, --) | Low (10, 08) | Low (--, --) | Low (06, 08) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 55 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: D1. When a wheel and axle is turned, a point on the rim of the wheel travels farther than does a point on the rim of the axle.

Test Item Generalization: 28. If a bicycle wheel is turned, then the point farthest from the wheel's center will travel farthest.

A-38

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (29, 42) | High (37, 45) | High (25, 38) | High (17, 25) |
| 6 (15, 24) | Mid. (12, 23) | Mid. (15, 26) | Mid. (10, 18) | Mid. (17, 27) |
| | Low (01, 05) | Low (03, 12) | Low (02, 01) | Low (02, 03) |
| | High (18, 27) | High (24, 33) | High (17, 32) | High (16, 25) |
| 5 (11, 20) | Mid. (10, 22) | Mid. (11, 20) | Mid. (08, 17) | Mid. (10, 21) |
| | Low (03, 02) | Low (05, 12) | Low (08, 09) | Low (07, 08) |
| | High (--, --) | High (--, --) | High (13, 22) | High (11, 19) |
| 4 (04, 10) | Mid. (01, 06) | Mid. (01, 09) | Mid. (02, 07) | Mid. (03, 09) |
| | Low (--, --) | Low (04, 05) | Low (--, --) | Low (03, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 56 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: D1. When a wheel and axle is turned, a point on the rim of the wheel travels farther than a point on the rim of the axle.

Test Item Generalization: 33. If there are many wheel and axle machines, then the widest axle has the largest axle arm.

A-39

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (75, 72) | High (72, 77) | High (67, 69) | High (60, 58) |
| 6 (67, 64) | Mid. (62, 61) | Mid. (66, 64) | Mid. (68, 60) | Mid. (66, 66) |
| | Low (68, 64) | Low (63, 57) | Low (72, 68) | Low (79, 68) |
| | High (67, 65) | High (67, 64) | High (61, 58) | High (64, 65) |
| 5 (63, 61) | Mid. (62, 62) | Mid. (65, 64) | Mid. (67, 65) | Mid. (59, 61) |
| | Low (61, 44) | Low (61, 53) | Low (58, 45) | Low (67, 50) |
| | High (--, --) | High (--, --) | High (74, 74) | High (74, 67) |
| 4 (60, 61) | Mid. (58, 60) | Mid. (63, 65) | Mid. (60, 56) | Mid. (59, 58) |
| | Low (--, --) | Low (52, 51) | Low (--, --) | Low (53, 63) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 57 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization:** D2. When a wheel and axle is turned, the edge of the wheel travels faster than the edge of the axle.

**Test Item Generalization:** 29. If an airplane propeller turns, then the point farthest from the center travels farthest and fastest.

A-40

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (17, 26) | High (17, 21) | High (15, 23) | High (10, 14) |
| 6 (09, 15) | Mid. (06, 12) | Mid. (09, 17) | Mid. (07, 13) | Mid. (10, 17) |
| | Low (03, 06) | Low (05, 08) | Low (02, 03) | Low (02, 01) |
| | High (10, 26) | High (19, 31) | High (10, 23) | High (11, 19) |
| 5 (06, 14) | Mid. (05, 08) | Mid. (06, 11) | Mid. (05, 11) | Mid. (05, 13) |
| | Low (01, 01) | Low (01, 07) | Low (01, 01) | Low (02, 06) |
| | High (--, --) | High (--, --) | High (13, 22) | High (11, 14) |
| 4 (07, 07) | Mid. (05, 06) | Mid. (07, 07) | Mid. (04, 02) | Mid. (09, 06) |
| | Low (--, --) | Low (02, 01) | Low (--, --) | Low (01, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 58 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: D2. When a wheel and axle is turned, the edge of the wheel travels faster than the edge of the axle.

Test Item Generalization: 30. If a fan blade turns, then the point farthest from the center travels fastest.

A-41

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| 6 (06, 09) | High (10, 16) | High (08, 07) | High (09, 13) | High (08, 07) |
| | Mid. (03, 07) | Mid. (06, 13) | Mid. (06, 09) | Mid. (06, 12) |
| | Low (05, 02) | Low (07, 05) | Low (05, 03) | Low (02, 03) |
| 5 (04, 11) | High (07, 23) | High (07, 22) | High (07, 21) | High (08, 16) |
| | Mid. (03, 08) | Mid. (07, 14) | Mid. (03, 08) | Mid. (04, 11) |
| | Low (01, 01) | Low (01, 02) | Low (03, 05) | Low (01, 02) |
| 4 (05, 07) | High (--, --) | High (--, --) | High (09, 19) | High (11, 24) |
| | Mid. (01, 04) | Mid. (03, 04) | Mid. (06, 04) | Mid. (04, 04) |
| | Low (--, --) | Low (04, 03) | Low (--, --) | Low (03, 01) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 59 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: D3. A small force on the wheel will move a heavy load on the axle.

Test Item Generalization: 31. If a wheel and axle is used, then a small force on the large wheel moves a large load on the axle.

A-42

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (06, 05) | High (05, 03) | High (03, 04) | High (02, 02) | High (07, 05) |
| | Mid. (06, 05) | Mid. (07, 05) | Mid. (07, 04) | Mid. (06, 06) |
| | Low (08, 09) | Low (07, 07) | Low (16, 15) | Low (08, 05) |
| 5 (08, 03) | High (04, 01) | High (02, 01) | High (03, 01) | High (04, 02) |
| | Mid. (08, 04) | Mid. (07, 02) | Mid. (09, 06) | Mid. (10, 03) |
| | Low (12, 04) | Low (11, 05) | Low (15, 05) | Low (09, 04) |
| 4 (08, 09) | High (--, --) | High (--, --) | High (04, 07) | High (01, 05) |
| | Mid. (08, 09) | Mid. (10, 06) | Mid. (11, 05) | Mid. (10, 08) |
| | Low (--, --) | Low (06, 11) | Low (--, --) | Low (06, 17) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 60 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization:** D4. As the wheel becomes larger, it takes less force on the wheel to move the same load on the axle.

**Test Item Generalization:** 32. If a screw driver is used as a wheel and axle, then the widest handle uses the least effort force.

A-43

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (04, 04) | High (05, 05) | High (08, 04) | High (03, 07) | High (03, 03) |
| | Mid. (04, 03) | Mid. (01, 02) | Mid. (04, 02) | Mid. (04, 03) |
| | Low (03, 05) | Low (07, 05) | Low (07, 09) | Low (03, 08) |
| 5 (04, 06) | High (08, 12) | High (12, 08) | High (05, 08) | High (05, 09) |
| | Mid. (01, 02) | Mid. (03, 04) | Mid. (04, 05) | Mid. (04, 04) |
| | Low (01, 02) | Low (02, 03) | Low (03, 01) | Low (02, 04) |
| 4 (01, 02) | High (--, --) | High (--, --) | High (01, 04) | High (01, 10) |
| | Mid. (01, 02) | Mid. (01, 01) | Mid. (01, 02) | Mid. (01, 01) |
| | Low (--, --) | Low (02, 03) | Low (--, --) | Low (03, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 61 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: D4. As the wheel becomes larger, it takes less force on the wheel to move the same load on the axle.

Test Item Generalization: 34. If a wheel and axle is used and the axles are equal, then the largest wheel uses the least force to move a load.

A-44

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| 6 (52, 53) | High (66, 68) | High (57, 68) | High (56, 64) | High (47, 50) |
| | Mid. (48, 50) | Mid. (56, 59) | Mid. (50, 52) | Mid. (53, 55) |
| | Low (46, 38) | Low (45, 37) | Low (42, 35) | Low (57, 53) |
| 5 (40, 46) | High (53, 53) | High (52, 64) | High (50, 58) | High (41, 40) |
| | Mid. (37, 48) | Mid. (44, 48) | Mid. (41, 42) | Mid. (40, 49) |
| | Low (28, 27) | Low (31, 40) | Low (25, 32) | Low (38, 50) |
| 4 (40, 34) | High (--, --) | High (--, --) | High (39, 37) | High (37, 38) |
| | Mid. (40, 35) | Mid. (44, 41) | Mid. (40, 33) | Mid. (38, 30) |
| | Low (--, --) | Low (38, 27) | Low (--, --) | Low (45, 38) |

*First numeral in parentheses indicates probable success before instruction (success on M12). Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 62 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization:** E1. An inclined plane is another kind of simple machine.

**Test Item Generalization:** 35. If it is a staircase, then it is an inclined plane.

A-45

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (29, 69) | High (41, 86) | High (37, 91) | High (39, 89) | High (42, 78) |
| | Mid. (30, 73) | Mid. (32, 75) | Mid. (26, 66) | Mid. (28, 72) |
| | Low (16, 40) | Low (21, 52) | Low (07, 26) | Low (08, 15) |
| 5 (16, 60) | High (21, 86) | High (26, 78) | High (19, 78) | High (19, 65) |
| | Mid. (16, 55) | Mid. (17, 71) | Mid. (16, 56) | Mid. (16, 67) |
| | Low (08, 25) | Low (09, 41) | Low (05, 27) | Low (10, 30) |
| 4 (23, 55) | High (--, --) | High (--, --) | High (26, 67) | High (11, 43) |
| | Mid. (22, 51) | Mid. (21, 55) | Mid. (23, 58) | Mid. (33, 59) |
| | Low (--, --) | Low (18, 49) | Low (--, --) | Low (08, 46) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 63 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: E3. Wedges and screws are special forms of the inclined plane.

Test Item Generalization: 36. If some screws are the same size and used in wood, then the screw with the most threads is easiest to use.

A-46

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (37, 54) | High (38, 59) | High (31, 52) | High (26, 39) |
| 6 (32, 43) | Mid. (27, 42) | Mid. (31, 45) | Mid. (30, 39) | Mid. (34, 49) |
| | Low (33, 31) | Low (28, 33) | Low (26, 21) | Low (30, 15) |
| | High (39, 67) | High (36, 50) | High (31, 60) | High (24, 52) |
| 5 (25, 50) | Mid. (17, 43) | Mid. (29, 55) | Mid. (25, 44) | Mid. (30, 58) |
| | Low (19, 38) | Low (16, 41) | Low (15, 36) | Low (17, 20) |
| | High (--, --) | High (--, --) | High (35, 56) | High (32, 52) |
| 4 (25, 47) | Mid. (27, 49) | Mid. (30, 51) | Mid. (30, 44) | Mid. (30, 51) |
| | Low (--, --) | Low (12, 32) | Low (--, --) | Low (08, 25) |

*First numeral in parentheses indicates probable success before instruction (success on M12). Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 64 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization:** E3. Wedges and screws are special forms of the inclined plane.

**Test Item Generalization:** 37. If a wedge is used in wood, then the narrowest wedge is easiest to use.

A-47

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (72, 82) | High (58, 82) | High (66, 79) | High (57, 64) |
| 6 (62, 69) | Mid. (58, 64) | Mid. (67, 70) | Mid. (61, 67) | Mid. (66, 72) |
| | Low (56, 59) | Low (56, 62) | Low (49, 62) | Low (60, 65) |
| | High (64, 82) | High (62, 64) | High (57, 72) | High (53, 66) |
| 5 (55, 67) | Mid. (54, 65) | Mid. (59, 72) | Mid. (60, 70) | Mid. (60, 71) |
| | Low (43, 48) | Low (50, 60) | Low (43, 32) | Low (47, 54) |
| | High (--, --) | High (--, --) | High (57, 78) | High (68, 67) |
| 4 (45, 57) | Mid. (47, 55) | Mid. (49, 58) | Mid. (51, 58) | Mid. (44, 57) |
| | Low (--, --) | Low (38, 51) | Low (--, --) | Low (33, 42) |

*First numeral in parentheses indicates probable success before instruction (success on M12). Second numeral in parentheses indicates probable success after instruction (success on M23).

Table65 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: F1. Friction is a force resisting motion between two surfaces in contact.

Test Item Generalization: 38. If a stick man sits in a boat and doesn't touch the sail, then friction does not exist between him and the sail.

A-48

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (25, 47) | High (31, 55) | High (20, 39) | High (14, 25) |
| 6 (16, 27) | Mid. (13, 23) | Mid. (17, 32) | Mid. (14, 21) | Mid. (18, 32) |
| | Low (10, 13) | Low (10, 10) | Low (02, 06) | Low (14, 05) |
| | High (18, 36) | High (24, 31) | High (16, 36) | High (08, 22) |
| 5 (08, 22) | Mid. (02, 18) | Mid. (04, 25) | Mid. (04, 17) | Mid. (09, 26) |
| | Low (01, 04) | Low (03, 09) | Low (01, 09) | Low (06, 12) |
| | High (--, --) | High (--, --) | High (09, 37) | High (01, 29) |
| 4 (04, 17) | Mid. (04, 11) | Mid. (04, 17) | Mid. (02, 12) | Mid. (05, 16) |
| | Low (--, --) | Low (02, 14) | Low (--, --) | Low (03, 08) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 66 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: F1. Friction is a force resisting motion between two surfaces in contact.

Test Item Generalization: 39. If a box is moved over a surface and a stick man stands on the box, then friction is greatest where the surface and box touch.

A-49

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (35, 64) | High (38, 75) | High (30, 66) | High (25, 46) |
| 6 (23, 45) | Mid. (24, 47) | Mid. (25, 47) | Mid. (17, 34) | Mid. (26, 49) |
| | Low (08, 18) | Low (13, 26) | Low (09, 12) | Low (10, 13) |
| | High (23, 51) | High (26, 44) | High (19, 50) | High (15, 47) |
| 5 (13, 38) | Mid. (10, 35) | Mid. (17, 39) | Mid. (11, 37) | Mid. (13, 36) |
| | Low (01, 13) | Low (04, 29) | Low (01, 09) | Low (10, 26) |
| | High (--, --) | High (--, --) | High (13, 37) | High (11, 38) |
| 4 (10, 24) | Mid. (12, 21) | Mid. (08, 26) | Mid. (09, 19) | Mid. (09, 23) |
| | Low (--, --) | Low (06, 14) | Low (--, --) | Low (11, 13) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 67 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: F1. Friction is a force resisting motion between two surfaces in contact.

Test Item Generalization: 40. If a wagon and stick man do not touch, then friction does not exist between them.

A-50

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (32, 42) | High (39, 59) | High (49, 75) | High (35, 57) | High (30, 45) |
| | Mid. (31, 37) | Mid. (35, 45) | Mid. (30, 35) | Mid. (34, 43) |
| | Low (24, 27) | Low (20, 20) | Low (14, 15) | Low (27, 25) |
| 5 (24, 32) | High (31, 49) | High (26, 39) | High (27, 54) | High (25, 37) |
| | Mid. (23, 26) | Mid. (27, 36) | Mid. (23, 19) | Mid. (22, 29) |
| | Low (16, 15) | Low (20, 19) | Low (18, 23) | Low (24, 32) |
| 4 (17, 27) | High (--, --) | High (--, --) | High (13, 67) | High (11, 43) |
| | Mid. (17, 23) | Mid. (20, 32) | Mid. (21, 16) | Mid. (18, 27) |
| | Low (--, --) | Low (16, 14) | Low (--, --) | Low (19, 13) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 68 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: F2. Friction produces heat.

Test Item Generalization: 41. If your hands are rubbed together quickly, then friction between them causes warmth.

A-51

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (59, 73) | High (79, 90) | High (85, 91) | High (73, 91) | High (61, 78) |
| | Mid. (55, 74) | Mid. (63, 81) | Mid. (49, 66) | Mid. (65, 76) |
| | Low (37, 51) | Low (40, 53) | Low (28, 44) | Low (29, 40) |
| 5 (51, 72) | High (77, 91) | High (71, 86) | High (74, 87) | High (54, 81) |
| | Mid. (46, 71) | Mid. (56, 75) | Mid. (47, 71) | Mid. (58, 70) |
| | Low (21, 40) | Low (35, 56) | Low (15, 32) | Low (32, 56) |
| 4 (21, 53) | High (--, --) | High (--, --) | High (39, 59) | High (42, 71) |
| | Mid. (19, 59) | Mid. (18, 51) | Mid. (19, 56) | Mid. (19, 48) |
| | Low (--, --) | Low (18, 54) | Low (--, --) | Low (14, 50) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 69 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

**Generalization**: F3. There is some friction in every machine when it is being used.

**Test Item Generalization**: 42. If a fan or roller skate or airplane is used, then it has some friction.

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (33, 42) | High (38, 59) | High (38, 71) | High (39, 53) | High (33, 43) |
| | Mid. (33, 39) | Mid. (36, 42) | Mid. (31, 39) | Mid. (34, 44) |
| | Low (28, 28) | Low (27, 30) | Low (21, 24) | Low (30, 30) |
| 5 (28, 39) | High (32, 55) | High (36, 39) | High (31, 46) | High (28, 48) |
| | Mid. (21, 32) | Mid. (27, 39) | Mid. (27, 38) | Mid. (29, 38) |
| | Low (25, 25) | Low (21, 34) | Low (23, 27) | Low (24, 20) |
| 4 (12, 17) | High (--, --) | High (--, --) | High (17, 33) | High (21, 29) |
| | Mid. (12, 15) | Mid. (11, 20) | Mid. (09, 12) | Mid. (14, 19) |
| | Low (--, --) | Low (14, 08) | Low (--, --) | Low (03, 01) |

*First numeral in parentheses indicates probable success before instruction (success on M12). Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 70 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: F5. Sliding friction is important in writing, walking, running.

Test Item Generalization: 43. If something is written on a chalkboard, then this is an example of sliding friction.

A-53

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|  | High (26, 48) | High (31, 66) | High (23, 38) | High (17, 23) |
| 6 (16, 28) | Mid. (14, 25) | Mid. (15, 23) | Mid. (13, 23) | Mid. (16, 34) |
|  | Low (05, 13) | Low (09, 16) | Low (01, 01) | Low (11, 05) |
|  | High (18, 35) | High (12, 39) | High (17, 38) | High (11, 27) |
| 5 (10, 23) | Mid. (08, 22) | Mid. (15, 24) | Mid. (08, 18) | Mid. (11, 25) |
|  | Low (04, 04) | Low (03, 14) | Low (03, 05) | Low (07, 10) |
|  | High (--, --) | High (--, --) | High (01, 22) | High (01, 19) |
| 4 (02, 20) | Mid. (01, 21) | Mid. (01, 17) | Mid. (02, 21) | Mid. (03, 25) |
|  | Low (--, --) | Low (04, 16) | Low (--, --) | Low (03, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12). Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 71 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: F6. Fluid friction is important to objects traveling through air, water, or other fluids.

Test Item Generalization: 44. If it is the Mississippi River or a thunderstorm or a swimmer, then this is an example of fluid friction.

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (19, 30) | High (20, 34) | High (16, 21) | High (14, 15) |
| 6 (16, 19) | Mid. (15, 15) | Mid. (18, 17) | Mid. (17, 18) | Mid. (16, 22) |
| | Low (15, 14) | Low (13, 16) | Low (14, 15) | Low (22, 18) |
| | High (15, 22) | High (26, 39) | High (16, 35) | High (15, 19) |
| 5 (14, 24) | Mid. (13, 24) | Mid. (14, 26) | Mid. (13, 19) | Mid. (12, 27) |
| | Low (12, 13) | Low (11, 16) | Low (18, 32) | Low (17, 22) |
| | High (--, --) | High (--, --) | High (22, 19) | High (05, 05) |
| 4 (11, 14) | Mid. (10, 13) | Mid. (08, 16) | Mid. (08, 11) | Mid. (14, 19) |
| | Low (--, --) | Low (10, 05) | Low (--, --) | Low (06, 04) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 72 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: F6. Fluid friction is important to objects traveling through air, water or other fluids.

Test Item Generalization: 46. If an object travels through air, then fluid friction affects it.

A-55

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (11, 07) | High (02, 06) | High (05, 05) | High (06, 05) | High (11, 05) |
| | Mid. (15, 07) | Mid. (09, 07) | Mid. (11, 08) | Mid. (08, 07) |
| | Low (18, 10) | Low (16, 09) | Low (26, 06) | Low (22, 15) |
| 5 (09, 16) | High (08, 23) | High (07, 06) | High (11, 20) | High (08, 22) |
| | Mid. (11, 15) | Mid. (11, 15) | Mid. (09, 14) | Mid. (12, 14) |
| | Low (08, 13) | Low (10, 16) | Low (03, 09) | Low (07, 08) |
| 4 (05, 15) | High (--, --) | High (--, --) | High (04, 22) | High (05, 14) |
| | Mid. (06, 15) | Mid. (04, 16) | Mid. (04, 12) | Mid. (08, 16) |
| | Low (--, --) | Low (06, 11) | Low (--, --) | Low (01, 08) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 73 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: F7. Rolling friction is important to the use of automobiles, roller skates, bicycles.

Test Item Generalization: 45. If a bike is rolling on the sidewalk, then this is an example of rolling friction.

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (67, 73) | High (75, 90) | High (75, 95) | High (75, 87) | High (73, 78) |
| | Mid. (70, 71) | Mid. (73, 77) | Mid. (64, 67) | Mid. (66, 74) |
| | Low (54, 55) | Low (54, 57) | Low (49, 44) | Low (59, 46) |
| 5 (55, 69) | High (75, 82) | High (79, 89) | High (76, 88) | High (61, 71) |
| | Mid. (54, 71) | Mid. (59, 76) | Mid. (52, 68) | Mid. (58, 71) |
| | Low (28, 42) | Low (41, 57) | Low (28, 36) | Low (41, 56) |
| 4 (48, 54) | High (--, --) | High (--, --) | High (78, 78) | High (58, 62) |
| | Mid. (49, 57) | Mid. (49, 58) | Mid. (38, 54) | Mid. (47, 61) |
| | Low (--, --) | Low (36, 41) | Low (--, --) | Low (42, 21) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

Table 74 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT MACHINES*

Generalization: F7. Rolling friction is important to use of automobiles, roller skates, bicycles.

Test Item Generalization: 47. If bicycles or automobiles or roller skates are used, then rolling friction affects them.

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (77, 84) | High (83, 93) | High (71, 78) | High (58, 65) |
| 6 (61, 68) | Mid. (63, 72) | Mid. (67, 77) | Mid. (55, 65) | Mid. (67, 75) |
| | Low (37, 43) | Low (39, 46) | Low (33, 44) | Low (38, 40) |
| | High (70, 79) | High (69, 72) | High (68, 75) | High (51, 65) |
| 5 (54, 64) | Mid. (53, 66) | Mid. (60, 73) | Mid. (50, 61) | Mid. (58, 64) |
| | Low (32, 33) | Low (42, 49) | Low (38, 45) | Low (48, 58) |
| | High (--, --) | High (--, --) | High (57, 56) | High (58, 57) |
| 4 (35, 40) | Mid. (33, 44) | Mid. (39, 49) | Mid. (32, 40) | Mid. (34, 44) |
| | Low (--, --) | Low (26, 16) | Low (--, --) | Low (22, 08) |

*First numeral in parentheses indicates probable success before instruction (success on M12).
Second numeral in parentheses indicates probable success after instruction (success on M23).

# Appendix B-1

## LIST OF GENERALIZATIONS ABOUT ELECTRICITY WITH CORRESPONDING TEST ITEMS

### A. ELECTRICAL ENERGY

2. Electrical energy is produced by the flow of charged bodies. (Test Item 21)

3. The energy from light, heat, mechanical forces, or chemical action may be changed to electrical energy. (Test Item 19)

### B. STATIC ELECTRICITY--ATOMIC STRUCTURE

1. All matter is made of atoms. (Test Item 18)

2. Every atom has a nucleus. (Test Items 22, 5)

3. Around each nucleus of an atom are electrons. (Test Items 2, 3)

4. The nucleus of an atom has a positive electrical charge. (Test Item 4)

5. The electrons around the nucleus have a negative charge. Test Item 1)

6. A neutral substance becomes positively charged when it gives up electrons. (Test Items 12, 9)

7. A neutral substance becomes negatively charged when it takes on additional electrons. (Test Items 11, 8)

8. Neutral objects are neither positively nor negatively charged. (Test Item 6)

9. Like electrical charges repel each other, but unlike electrical charges attract. (Test Items 7, 10)

### C. STATIC ELECTRICITY--ELECTRICAL CHARGES

1. Some materials readily give up electrons, while other materials readily capture electrons. (Test Items 13, 15)

2. Electricity produced by rubbing one material with another material is called static or frictional electricity. (Test Item 16)

3. Electrical charges collect on the surface of a material. (Test Item 17)

5. Neutral objects can be attracted by either positively or negatively charged objects. (Test Item 14)

## D. CURRENT ELECTRICITY--OPEN AND CLOSED CIRCUITS

1. When electrons move along a conductor, an electric current is produced. (Test Item 20)

3. An electric circuit contains a source of electrical energy and a path through which the current may flow. (Test Items 25, 26)

4. A closed circuit has no gaps in the path of the current of electricity. (Test Items 24, 30)

6. An electric circuit may be connected in series or in parallel. (Test Items 27, 28, 29)

## E. CURRENT ELECTRICITY--CONDUCTORS AND NON-CONDUCTORS

1. All materials offer some resistance to an electric current. (Test Item 37)

2. An electric current flows easily along good conductors of electricity. (Test Item 32)

5. When an electric current flows along a wire, the wire is heated. (Test Items 38, 39)

6. In electrical heating appliances a current is sent along a wire which is a poor conductor. (Test Items 35, 36)

7. When a large electric current flows along a wire which is a poor conductor, it may become hot enough to give off light. (Test Item 40)

## F. CURRENT ELECTRICITY--DIRECT CURRENT AND ALTERNATING CURRENT

1. The chemical changes in an electric cell provide an excess of electrons at the negative terminal and few electrons at the positive terminal. (Test Items 31, 34)

2. The increase of electrons at a terminal forms a force which moves electrons along a conductor. (Test Item 33)

3. Electrons from the negative terminal of a cell will readily flow along a conductor tending to equalize the number of electrons at each terminal. (Test Item 44, 43)

4. Since current produced by a cell flows in one direction only, it is called direct current. (Test Item 47)

5. Alternating currents flow first in one direction and then in the opposite direction. (Test Item 50)

6. Electricity from a generator may be either direct current (DC) or alternating current (AC). (Test Item 45)

7. Electric current may be used to: heat or cook, make light, send messages, and run machines. (Test Item 23)

## G. ELECTROMAGNETS

1. Moving a solid conductor through a magnetic field will generate an electric current. (Test Items 41, 42)

3. An electromagnet consists of a piece of iron within a coil of wire, along which a current of electricity is sent. (Test Item 48)

6. An electromagnet has considerable force only so long as the electric current is flowing. (Test Item 49)

7. Electromagnets are important parts of electric motors. (Test Item 46)

Table 75 NUMBER OF PUPILS USED IN EACH GRADE GROUP AND WITH TEST VARIABLES TO ESTABLISH PROBABILITY ESTIMATES OF SUCCESS FOR GENERALIZATIONS ABOUT ELECTRICITY

B-4

| | | | Science Bkgd. | | Read. Comp. | | Intel. Quot. | | Soc-Econ. |
|---|---|---|---|---|---|---|---|---|---|
| | E12 E23 | | E12 E23 | | E12 E23 | | E12 E23 | | E12 E23 |
| | | High | ( 96, 97) | High | ( 44, 50) | High | (108,115) | High | (106,119) |
| Grade 6 | (338,404) | Mid | (128,151) | Mid | (154,168) | Mid | (156,159) | Mid | (198,225) |
| | | Low | ( 81, 83) | Low | (119,100) | Low | ( 24,---) | Low | ( 36, 62) |
| | E12 E23 | | E12 E23 | | E12 E23 | | E12 E23 | | E12 E23 |
| | | High | ( 75, 83) | High | ( 29, 27) | High | ( 93, 96) | High | ( 89, 99) |
| Grade 5 | (282,315) | Mid | (120,121) | Mid | (119,121) | Mid | (130,136) | Mid | (157,165) |
| | | Low | ( 44, 39) | Low | ( 83, 85) | Low | ( 16,---) | Low | ( 38, 53) |
| | E12 E23 | | E12 E23 | | E12 E23 | | E12 E23 | | E12 E23 |
| | | High | ( 19, 22) | High | (---,---) | High | ( 26, 29) | High | ( 24, 28) |
| Grade 4 | (139, 173) | Mid | ( 87, 86) | Mid | ( 73, 74) | Mid | ( 61, 62) | Mid | ( 85, 95) |
| | | Low | (---, 16) | Low | ( 38, 43) | Low | (---,---) | Low | ( 32, 52) |

In grade 6, there were 338 pupils used to establish probability estimates for each generalization on the double precision test (E12) and 404 pupils were used for the (E23) test. Probability estimates are not reported for samples of 15 pupils or less.

Table 76 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: A2. Electrical energy is produced by a flow of charged bodies.

Test Item Generalization: 21. If it is electricity, then it is a flow of electrons.

B-5

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (63, 56) | High (59, 56) | High (53, 51) | High (47, 43) |
| 6 (46, 40) | Mid. (42, 40) | Mid. (53, 42) | Mid. (40, 34) | Mid. (45, 41) |
| | Low (33, 29) | Low (33, 32) | Low (33, --) | Low (39, 29) |
| | High (41, 46) | High (28, 41) | High (39, 50) | High (31, 33) |
| 5 (32, 34) | Mid. (27, 26) | Mid. (36, 30) | Mid. (30, 24) | Mid. (34, 33) |
| | Low (18, 15) | Low (22, 22) | Low (19, --) | Low (26, 35) |
| | High (37, 41) | High (--, --) | High (38, 31) | High (33, 21) |
| 4 (33, 20) | Mid. (38, 22) | Mid. (36, 20) | Mid. (31, 18) | Mid. (40, 24) |
| | Low (--, 06) | Low (24, 16) | Low (--, --) | Low (13, 10) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 77 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: A3. Energy from light, heat, mechanical forces, or chemical action may be changed to electrical energy.

Test Item Generalization: 19. If it is an electric motor, then it can use energy from sunlight or waterfalls or burning candle.

B-6

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| 6 (12, 16) | High (15, 24) | High (18, 20) | High (13, 18) | High (14, 15) |
| | Mid. (12, 14) | Mid. (12, 20) | Mid. (12, 18) | Mid. (12, 18) |
| | Low (07, 14) | Low (08, 14) | Low (13, --) | Low (11, 11) |
| 5 (12, 16) | High (12, 23) | High (07, 07) | High (11, 18) | High (12, 13) |
| | Mid. (14, 17) | Mid. (11, 19) | Mid. (12, 16) | Mid. (12, 19) |
| | Low (09, 03) | Low (14, 09) | Low (19, --) | Low (11, 11) |
| 4 (12, 13) | High (01, 05) | High (--, --) | High (08, 03) | High (21, 14) |
| | Mid. (14, 12) | Mid. (11, 12) | Mid. (15, 15) | Mid. (13, 13) |
| | Low (--, 19) | Low (18, 14) | Low (--, --) | Low (01, 12) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 78 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

**Generalization:** B1. All matter is made of atoms.

**Test Item Generalization:** 18. If they are atoms, then there are more than one million in a small box.

B-7

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (41, 58) | High (47, 63) | High (52, 62) | High (56, 66) | High (56, 61) |
|  | Mid. (46, 60) | Mid. (45, 61) | Mid. (33, 55) | Mid. (37, 60) |
|  | Low (22, 46) | Low (31, 54) | Low (21, --) | Low (22, 47) |
| 5 (32, 56) | High (41, 65) | High (31, 56) | High (37, 64) | High (38, 45) |
|  | Mid. (27, 53) | Mid. (31, 59) | Mid. (29, 53) | Mid. (32, 65) |
|  | Low (27, 38) | Low (31, 47) | Low (19, --) | Low (13, 43) |
| 4 (24, 42) | High (26, 45) | High (--, --) | High (23, 59) | High (38, 46) |
|  | Mid. (25, 55) | Mid. (25, 49) | Mid. (26, 48) | Mid. (20, 47) |
|  | Low (--, 13) | Low (24, 37) | Low (--, --) | Low (22, 27) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 79 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

**Generalization:** B2. Every atom has a nucleus.

**Test Item Generalization:** 22. If it is the nucleus, then it is at the center of the atom.

B-8

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|  | High (29, 77) | High (52, 78) | High (31, 72) | High (28, 57) |
| 6 (23, 53) | Mid. (22, 55) | Mid. (21, 61) | Mid. (15, 45) | Mid. (20, 59) |
|  | Low (19, 30) | Low (17, 37) | Low (21, --) | Low (25, 21) |
|  | High (25, 72) | High (31, 67) | High (20, 66) | High (21, 51) |
| 5 (13, 46) | Mid. (06, 37) | Mid. (12, 56) | Mid. (07, 40) | Mid. (10, 47) |
|  | Low (11, 15) | Low (06, 27) | Low (06, --) | Low (03, 30) |
|  | High (11, 73) | High (--, --) | High (08, 62) | High (04, 36) |
| 4 (10, 25) | Mid. (10, 21) | Mid. (12, 30) | Mid. (11, 19) | Mid. (12, 32) |
|  | Low (--, 06) | Low (08, 14) | Low (--, --) | Low (09, 08) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 80 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: B2. Every atom has a nucleus.

Test Item Generalization: 5. If it is an atom, then the nucleus is at the center.

B-9

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (18, 51) | High (28, 76) | High (41, 76) | High (22, 74) | High (23, 55) |
| | Mid. (17, 52) | Mid. (17, 63) | Mid. (13, 43) | Mid. (18, 60) |
| | Low (07, 29) | Low (11, 37) | Low (04, --) | Low (08, 08) |
| 5 (11, 42) | High (21, 69) | High (14, 59) | High (20, 60) | High (16, 53) |
| | Mid. (06, 30) | Mid. (08, 46) | Mid. (07, 35) | Mid. (11, 44) |
| | Low (07, 13) | Low (10, 26) | Low (06, --) | Low (01, 17) |
| 4 (08, 24) | High (16, 50) | High (--, --) | High (08, 52) | High (08, 32) |
| | Mid. (06, 26) | Mid. (05, 27) | Mid. (10, 19) | Mid. (11, 32) |
| | Low (--, 01) | Low (13, 19) | Low (--, --) | Low (01, 06) |

*First numeral in parentheses indicates probable success before instruction (success on E12). Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 81 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: B3. Around each nucleus of an atom are electrons.

Test Item Generalization: 2. If it is an atom, then it has an electron.

B-10

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| | High (26, 61) | High (30, 60) | High (20, 57) | High (15, 40) |
| 6 (18, 43) | Mid. (20, 46) | Mid. (16, 54) | Mid. (12, 38) | Mid. (20, 51) |
| | Low (07, 30) | Low (17, 33) | Low (13, --) | Low (14, 19) |
| | High (35, 48) | High (17, 37) | High (22, 47) | High (22, 30) |
| 5 (20, 35) | Mid. (13, 31) | Mid. (22, 43) | Mid. (23, 32) | Mid. (22, 41) |
| | Low (16, 15) | Low (14, 25) | Low (06, --) | Low (08, 26) |
| | High (42, 32) | High (--, --) | High (38, 41) | High (29, 18) |
| 4 (22, 23) | Mid. (25, 27) | Mid. (32, 31) | Mid. (23, 23) | Mid. (24, 33) |
| | Low (--, 01) | Low (08, 12) | Low (--, --) | Low (13, 08) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 82 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: B3. Around each nucleus of an atom are electrons.

Test Item Generalization: 3. If it is an atom, then it has an electron path around the nucleus.

B-11

| Grade Level | Information Known About Pupils | | | |
|---|---|---|---|---|
| | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (13, 29) | High (20, 47) | High (27, 58) | High (19, 43) | High (13, 41) |
| | Mid. (12, 30) | Mid. (12, 33) | Mid. (07, 21) | Mid. (13, 28) |
| | Low (04, 07) | Low (07, 15) | Low (08, --) | Low (08, 08) |
| 5 (12, 20) | High (23, 31) | High (07, 22) | High (13, 27) | High (11, 16) |
| | Mid. (08, 17) | Mid. (14, 22) | Mid. (12, 18) | Mid. (14, 25) |
| | Low (05, 10) | Low (06, 19) | Low (06, --) | Low (03, 09) |
| 4 (12, 14) | High (26, 27) | High (--, --) | High (19, 21) | High (08, 21) |
| | Mid. (10, 15) | Mid. (11, 14) | Mid. (07, 15) | Mid. (13, 17) |
| | Low (--, 01) | Low (11, 12) | Low (--, --) | Low (09, 04) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 83 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: B4. The nucleus of an atom has a positive electrical charge.

Test Item Generalization: 4. If it is an atom, then the greatest positive charge is at the nucleus.

B-12

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (21, 22) | High (26, 32) | High (23, 34) | High (23, 33) | High (21, 24) |
| | Mid. (20, 20) | Mid. (21, 21) | Mid. (22, 18) | Mid. (23, 24) |
| | Low (19, 17) | Low (19, 22) | Low (13, --) | Low (11, 06) |
| 5 (21, 21) | High (24, 25) | High (28, 19) | High (27, 27) | High (16, 15) |
| | Mid. (17, 17) | Mid. (18, 19) | Mid. (18, 20) | Mid. (22, 27) |
| | Low (07, 18) | Low (17, 19) | Low (13, --) | Low (24, 13) |
| 4 (22, 18) | High (26, 23) | High (--, --) | High (23, 28) | High (25, 21) |
| | Mid. (22, 21) | Mid. (25, 19) | Mid. (16, 16) | Mid. (20, 17) |
| | Low (--, 13) | Low (08, 14) | Low (--, --) | Low (25, 19) |

*First numeral in parentheses indicates probable success before instruction (success on E12). Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 84 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

**Generalization:** B5. The electrons around the nucleus have a negative charge.

**Test Item Generalization:** 1. If it is an atom, then the greatest negative charge is at electron B or electron C.

B-13

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (08, 13) | High (09, 27) | High (16, 28) | High (15, 25) | High (10, 19) |
|  | Mid. (09, 10) | Mid. (09, 13) | Mid. (05, 05) | Mid. (08, 12) |
|  | Low (04, 05) | Low (05, 09) | Low (04, --) | Low (01, 05) |
| 5 (06, 11) | High (08, 19) | High (10, 26) | High (09, 20) | High (03, 11) |
|  | Mid. (02, 06) | Mid. (03, 09) | Mid. (04, 07) | Mid. (06, 12) |
|  | Low (07, 10) | Low (08, 11) | Low (06, --) | Low (08, 08) |
| 4 (04, 05) | High (05, 18) | High (--, --) | High (12, 07) | High (04, 11) |
|  | Mid. (05, 05) | Mid. (01, 04) | Mid. (03, 05) | Mid. (05, 05) |
|  | Low (--, 01) | Low (05, 05) | Low (--, --) | Low (01, 02) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 85 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

**Generalization**: B6. A neutral substance becomes positively charged when it gives up electrons.

**Test Item Generalization**: 12. If an object has more positive charges than negative charges, then it is positively charged.

B-14

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (16, 36) | High (25, 51) | High (25, 66) | High (18, 50) | High (18, 41) |
| | Mid. (13, 40) | Mid. (15, 38) | Mid. (12, 28) | Mid. (16, 40) |
| | Low (10, 22) | Low (13, 28) | Low (08, --) | Low (08, 13) |
| 5 (15, 22) | High (23, 34) | High (14, 33) | High (19, 34) | High (17, 26) |
| | Mid. (10, 15) | Mid. (08, 23) | Mid. (12, 17) | Mid. (14, 24) |
| | Low (09, 13) | Low (17, 15) | Low (06, --) | Low (11, 09) |
| 4 (06, 13) | High (11, 14) | High (--, --) | High (12, 14) | High (04, 11) |
| | Mid. (07, 13) | Mid. (05, 09) | Mid. (03, 13) | Mid. (07, 16) |
| | Low (--, 06) | Low (05, 12) | Low (--, --) | Low (03, 08) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 86 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: B6. A neutral substance becomes positively charged when it gives up electrons.

Test Item Generalization: 9. If it is an atom and has two electrons and a nucleus of three protons, then it has a positive charge.

B-15

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (10, 15) | High (11, 22) | High (07, 15) | High (07, 18) |
| 6 (07, 12) | Mid. (05, 13) | Mid. (05, 10) | Mid. (03, 06) | Mid. (07, 09) |
| | Low (04, 07) | Low (06, 08) | Low (08, --) | Low (06, 06) |
| | High (03, 06) | High (01, 15) | High (03, 08) | High (03, 02) |
| 5 (05, 09) | Mid. (06, 06) | Mid. (03, 08) | Mid. (06, 11) | Mid. (06, 12) |
| | Low (05, 10) | Low (05, 06) | Low (06, --) | Low (05, 13) |
| | High (01, 05) | High (--, --) | High (01, 03) | High (01, 04) |
| 4 (01, 05) | Mid. (01, 03) | Mid. (01, 04) | Mid. (01, 02) | Mid. (01, 02) |
| | Low (--, 06) | Low (03, 02) | Low (--, --) | Low (03, 10) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 87 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: B7. A neutral substance becomes negatively charged when it takes on additional electrons.

Test Item Generalization: 11. If an object has more negative charges than positive charges, then it is negatively charged.

B-16

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (18, 48) | High (25, 60) | High (16, 48) | High (15, 34) |
| 6 (09, 31) | Mid. (08, 30) | Mid. (08, 33) | Mid. (03, 23) | Mid. (08, 35) |
| | Low (05, 14) | Low (07, 20) | Low (01, --) | Low (03, 10) |
| | High (11, 31) | High (03, 44) | High (10, 33) | High (06, 21) |
| 5 (05, 17) | Mid. (03, 10) | Mid. (03, 17) | Mid. (03, 11) | Mid. (05, 17) |
| | Low (01, 01) | Low (05, 08) | Low (06, --) | Low (03, 06) |
| | High (05, 14) | High (--, --) | High (08, 17) | High (01, 04) |
| 4 (04, 06) | Mid. (05, 06) | Mid. (03, 08) | Mid. (05, 02) | Mid. (07, 08) |
| | Low (--, 01) | Low (08, 01) | Low (--, --) | Low (01, 02) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 88 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

**Generalization**: B7. A neutral substance becomes negatively charged when it takes on additional electrons.

**Test Item Generalization**: 8. If it is an atom and has four electrons and a nucleus of three protons, then it has a negative charge.

B-17

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
|  | High (23, 28) | High (23, 28) | High (18, 24) | High (21, 24) |
| 6 (18, 22) | Mid. (14, 24) | Mid. (17, 23) | Mid. (19, 20) | Mid. (16, 23) |
|  | Low (22, 17) | Low (18, 20) | Low (17, --) | Low (19, 13) |
|  | High (17, 18) | High (17, 19) | High (17, 21) | High (12, 14) |
| 5 (16, 19) | Mid. (17, 18) | Mid. (16, 18) | Mid. (18, 22) | Mid. (18, 20) |
|  | Low (11, 21) | Low (18, 21) | Low (13, --) | Low (16, 23) |
|  | High (21, 18) | High (--, --) | High (15, 14) | High (17, 25) |
| 4 (14, 13) | Mid. (13, 13) | Mid. (15, 09) | Mid. (15, 13) | Mid. (16, 13) |
|  | Low (--, 01) | Low (08, 19) | Low (--, --) | Low (03, 08) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 89 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: B8. Neutral objects are neither positively nor negatively charged.

Test Item Generalization: 6. If it is an atom and has three electrons and three protons, then it is neutral.

B-18

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (04, 24) | High (05, 28) | High (06, 19) | High (03, 18) |
| 6 (03, 13) | Mid. (02, 11) | Mid. (02, 12) | Mid. (01, 08) | Mid. (03, 14) |
| | Low (02, 04) | Low (03, 09) | Low (01, --) | Low (03, 02) |
| | High (04, 12) | High (14, 19) | High (08, 11) | High (03, 05) |
| 5 (04, 09) | Mid. (03, 03) | Mid. (03, 06) | Mid. (04, 10) | Mid. (04, 12) |
| | Low (01, 01) | Low (02, 04) | Low (01, --) | Low (05, 06) |
| | High (01, 05) | High (--, --) | High (01, 03) | High (04, 01) |
| 4 (02, 02) | Mid. (02, 01) | Mid. (03, 03) | Mid. (03, 01) | Mid. (02, 03) |
| | Low (--, 01) | Low (03, 01) | Low (--, --) | Low (01, 01) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 90 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: B9. Like electrical charges repel each other, but unlike electrical charges attract.

Test Item Generalization: 7. If three atoms have neutral, positive, negative charges, then they will not repel one another.

B-19

| Grade Level | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
|  | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (08, 14) | High (08, 14) | High (09, 16) | High (09, 16) | High (12, 14) |
|  | Mid. (05, 17) | Mid. (05, 14) | Mid. (07, 14) | Mid. (05, 13) |
|  | Low (11, 12) | Low (11, 15) | Low (04, --) | Low (11, 16) |
| 5 (06, 07) | High (07, 08) | High (07, 15) | High (06, 08) | High (04, 09) |
|  | Mid. (06, 10) | Mid. (07, 09) | Mid. (07, 08) | Mid. (07, 05) |
|  | Low (02, 03) | Low (06, 05) | Low (06, --) | Low (08, 09) |
| 4 (04, 05) | High (11, 05) | High (--, --) | High (12, 10) | High (04, 01) |
|  | Mid. (03, 07) | Mid. (07, 05) | Mid. (02, 05) | Mid. (05, 06) |
|  | Low (--, 01) | Low (01, 02) | Low (--, --) | Low (03, 06) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 91 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: B9. Like electrical charges repel each other, but unlike electrical charges attract.

Test Item Generalization: 10. If three atoms have neutral, positive, negative charges, then all atoms attract one another.

B-20

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (07, 10) | High (13, 07) | High (14, 14) | High (12, 12) | High (13, 12) |
| | Mid. (07, 11) | Mid. (07, 08) | Mid. (06, 09) | Mid. (05, 09) |
| | Low (02, 12) | Low (06, 08) | Low (01, --) | Low (03, 08) |
| 5 (10, 09) | High (13, 07) | High (10, 15) | High (11, 08) | High (10, 09) |
| | Mid. (08, 11) | Mid. (12, 10) | Mid. (11, 10) | Mid. (11, 07) |
| | Low (05, 05) | Low (06, 06) | Low (01, --) | Low (03, 15) |
| 4 (04, 06) | High (05, 09) | High (--, --) | High (04, 17) | High (01, 11) |
| | Mid. (03, 08) | Mid. (04, 08) | Mid. (02, 05) | Mid. (04, 04) |
| | Low (--, 01) | Low (01, 02) | Low (--, --) | Low (09, 10) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 92 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: C1. Some materials readily give up electrons, while other materials readily capture electrons.

Test Item Generalization: 13. If an object has more positive charges than negative charges, then it will try to capture electrons.

B-21

| Grade Level | Information Known About Pupils | | | |
|---|---|---|---|---|
| | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (01, 06) | High (02, 14) | High (02, 12) | High (01, 10) | High (01, 12) |
| | Mid. (01, 03) | Mid. (01, 06) | Mid. (01, 02) | Mid. (02, 04) |
| | Low (02, 05) | Low (01, 04) | Low (04, --) | Low (03, 02) |
| 5 (01, 04) | High (01, 02) | High (01, 07) | High (01, 04) | High (03, 03) |
| | Mid. (01, 02) | Mid. (01, 02) | Mid. (02, 04) | Mid. (01, 05) |
| | Low (02, 01) | Low (02, 02) | Low (01, --) | Low (01, 01) |
| 4 (05, 04) | High (05, 05) | High (--, --) | High (04, 03) | High (04, 01) |
| | Mid. (05, 06) | Mid. (05, 04) | Mid. (03, 03) | Mid. (06, 06) |
| | Low (--, 01) | Low (03, 05) | Low (--, --) | Low (03, 02) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 93 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

**Generalization:** C1. Some materials readily give up electrons, while other materials readily capture electrons.

**Test Item Generalization:** 15. If an object has more electrons than protons, then it tries to release electrons.

B-22

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| | High (13, 31) | High (11, 28) | High (18, 39) | High (17, 34) |
| 6 (14, 22) | Mid. (16, 27) | Mid. (14, 27) | Mid. (11, 16) | Mid. (11, 20) |
| | Low (12, 12) | Low (15, 16) | Low (21, --) | Low (22, 10) |
| | High (07, 19) | High (07, 22) | High (09, 22) | High (04, 10) |
| 5 (11, 15) | Mid. (13, 10) | Mid. (12, 14) | Mid. (12, 10) | Mid. (13, 17) |
| | Low (11, 10) | Low (13, 08) | Low (19, --) | Low (18, 17) |
| | High (11, 09) | High (--, --) | High (08, 07) | High (08, 11) |
| 4 (08, 09) | Mid. (09, 15) | Mid. (12, 11) | Mid. (08, 13) | Mid. (08, 12) |
| | Low (--, 01) | Low (03, 07) | Low (--, --) | Low (06, 04) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 94 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

**Generalization**: C2. Electricity produced by rubbing one material with another is called static or frictional electricity.

**Test Item Generalization**: 16. If it is static electricity, then it is made by rubbing.

B-23

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (65, 72) | High (85, 84) | High (86, 86) | High (81, 83) | High (76, 77) |
| | Mid. (67, 76) | Mid. (75, 81) | Mid. (59, 71) | Mid. (65, 76) |
| | Low (37, 55) | Low (45, 60) | Low (33, --) | Low (31, 45) |
| 5 (55, 65) | High (73, 80) | High (66, 78) | High (75, 75) | High (58, 67) |
| | Mid. (53, 63) | Mid. (65, 61) | Mid. (47, 64) | Mid. (60, 69) |
| | Low (25, 41) | Low (31, 59) | Low (38, --) | Low (24, 49) |
| 4 (31, 49) | High (37, 68) | High (--, --) | High (31, 69) | High (38, 50) |
| | Mid. (32, 55) | Mid. (34, 54) | Mid. (36, 52) | Mid. (31, 55) |
| | Low (--, 31) | Low (29, 40) | Low (--, --) | Low (25, 37) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 95 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: C3. Electrical charges collect on the surface of a material.

Test Item Generalization: 17. If it is static electricity, then it will be on the surface of the object.

B-24

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (38, 46) | High (50, 56) | High (38, 48) | High (42, 49) |
| 6 (28, 34) | Mid. (32, 36) | Mid. (28, 36) | Mid. (24, 24) | Mid. (23, 30) |
| | Low (15, 23) | Low (23, 25) | Low (04, --) | Low (14, 23) |
| | High (44, 40) | High (45, 44) | High (43, 42) | High (29, 31) |
| 5 (28, 26) | Mid. (23, 22) | Mid. (29, 31) | Mid. (22, 20) | Mid. (31, 27) |
| | Low (05, 05) | Low (20, 15) | Low (13, --) | Low (13, 13) |
| | High (26, 18) | High (--, --) | High (19, 17) | High (13, 11) |
| 4 (08, 12) | Mid. (06, 13) | Mid. (07, 14) | Mid. (08, 08) | Mid. (08, 14) |
| | Low (--, 01) | Low (05, 05) | Low (--, --) | Low (03, 10) |

*First numeral in parentheses indicates probable success before instruction (success on E12). Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 96 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: C5. Neutral objects can be attracted by either positively or negatively charged objects.

Test Item Generalization: 14. If an object has negative charge or positive charge, then it attracts neutral objects.

B-25

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (13, 19) | High (11, 22) | High (08, 11) | High (08, 09) |
| 6 (07, 11) | Mid. (06, 07) | Mid. (06, 13) | Mid. (04, 09) | Mid. (08, 14) |
| | Low (02, 10) | Low (06, 07) | Low (04, --) | Low (03, 02) |
| | High (05, 11) | High (14, 19) | High (12, 19) | High (09, 13) |
| 5 (08, 11) | Mid. (10, 12) | Mid. (08, 11) | Mid. (07, 11) | Mid. (09, 09) |
| | Low (09, 18) | Low (10, 13) | Low (06, --) | Low (03, 13) |
| | High (16, 01) | High (--, --) | High (08, 03) | High (17, 04) |
| 4 (09, 10) | Mid. (06, 10) | Mid. (11, 09) | Mid. (07, 10) | Mid. (07, 12) |
| | Low (--, 25) | Low (03, 16) | Low (--, --) | Low (06, 10) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 97 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: D1. When electrons move along a conductor, an electric current is produced.

Test Item Generalization: 20. If electrons move along a wire, then this is called electric current.

B-26

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| | High (30, 33) | High (27, 34) | High (27, 23) | High (24, 14) |
| 6 (18, 15) | Mid. (14, 11) | Mid. (20, 18) | Mid. (13, 10) | Mid. (17, 17) |
| | Low (11, 08) | Low (12, 05) | Low (13, --) | Low (11, 08) |
| | High (21, 22) | High (34, 26) | High (29, 25) | High (15, 15) |
| 5 (18, 13) | Mid. (13, 08) | Mid. (21, 12) | Mid. (09, 07) | Mid. (18, 12) |
| | Low (16, 01) | Low (12, 09) | Low (06, --) | Low (21, 09) |
| | High (26, 23) | High (--, --) | High (19, 21) | High (17, 18) |
| 4 (11, 09) | Mid. (09, 05) | Mid. (16, 07) | Mid. (10, 06) | Mid. (12, 11) |
| | Low (--, 06) | Low (03, 09) | Low (--, --) | Low (03, 02) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 98 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: D3. An electric circuit contains a source of electrical energy and a path through which the current may flow.

Test Item Generalization: 25. If it is a cell, then it is a source of electricity.

B-27

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
|  | High (46, 64) | High (43, 74) | High (33, 43) | High (25, 36) |
| 6 (26, 32) | Mid. (18, 26) | Mid. (28, 34) | Mid. (20, 27) | Mid. (29, 37) |
|  | Low (16, 11) | Low (17, 17) | Low (08, --) | Low (14, 05) |
|  | High (41, 51) | High (34, 48) | High (38, 48) | High (22, 27) |
| 5 (22, 30) | Mid. (15, 21) | Mid. (24, 31) | Mid. (17, 26) | Mid. (25, 36) |
|  | Low (05, 03) | Low (08, 14) | Low (01, --) | Low (11, 15) |
|  | High (21, 45) | High (--, --) | High (23, 41) | High (17, 21) |
| 4 (11, 16) | Mid. (09, 14) | Mid. (15, 19) | Mid. (05, 10) | Mid. (12, 19) |
|  | Low (--, 01) | Low (03, 02) | Low (--, --) | Low (03, 06) |

*First numeral in parentheses indicates probable success before instruction (success on E12). Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 99 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

**Generalization**: D3. An electric circuit contains a source of electrical energy and a path through with the current may flow.

**Test Item Generalization**: 26. If there is a cell in a closed circuit, then electricity starts from the negative terminal of the cell.

B-28

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (07, 12) | High (08, 21) | High (07, 26) | High (12, 18) | High (12, 18) |
|  | Mid. (06, 11) | Mid. (07, 11) | Mid. (06, 12) | Mid. (06, 10) |
|  | Low (06, 06) | Low (06, 09) | Low (01, --) | Low (03, 06) |
| 5 (08, 09) | High (08, 12) | High (07, 15) | High (08, 10) | High (09, 17) |
|  | Mid. (05, 07) | Mid. (06, 08) | Mid. (07, 10) | Mid. (06, 05) |
|  | Low (07, 10) | Low (07, 09) | Low (06, --) | Low (08, 08) |
| 4 (03, 09) | High (16, 14) | High (--, --) | High (08, 14) | High (08, 11) |
|  | Mid. (01, 07) | Mid. (03, 04) | Mid. (01, 05) | Mid. (02, 07) |
|  | Low (--, 06) | Low (01, 09) | Low (--, --) | Low (01, 12) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 100 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: D4. Closed circuit has no gaps in the path of current of electricity.

Test Item Generalization: 24. If there is a switch in a closed circuit, then the switch is closed.

B-29

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (40, 55) | High (34, 60) | High (38, 50) | High (45, 48) |
| 6 (34, 43) | Mid. (40, 44) | Mid. (39, 46) | Mid. (35, 44) | Mid. (31, 44) |
| | Low (23, 31) | Low (28, 36) | Low (08, --) | Low (19, 29) |
| | High (37, 48) | High (21, 63) | High (34, 57) | High (27, 48) |
| 5 (30, 44) | Mid. (25, 38) | Mid. (26, 40) | Mid. (27, 38) | Mid. (35, 45) |
| | Low (32, 31) | Low (30, 31) | Low (25, --) | Low (13, 32) |
| | High (37, 50) | High (--, --) | High (31, 52) | High (33, 32) |
| 4 (24, 31) | Mid. (25, 35) | Mid. (21, 32) | Mid. (23, 32) | Mid. (27, 38) |
| | Low (--, 13) | Low (26, 26) | Low (--, --) | Low (09, 17) |

*First numeral in parentheses indicates probable success before instruction (success on E12). Second numeral in parentheses indicates probable success after instruction (success on E23).

Table101 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: D4. A closed circuit has no gaps in the path of current of electricity.

Test Item Generalization: 30. If electricity moves from the cell along the conductor and back to the cell, then that path is a closed circuit.

B-30

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (09, 17) | High (11, 26) | High (11, 32) | High (12, 23) | High (13, 20) |
| | Mid. (09, 14) | Mid. (10, 15) | Mid. (08, 14) | Mid. (07, 18) |
| | Low (07, 13) | Low (07, 16) | Low (01, --) | Low (08, 06) |
| 5 (05, 14) | High (08, 22) | High (07, 19) | High (10, 21) | High (04, 09) |
| | Mid. (04, 12) | Mid. (06, 15) | Mid. (02, 11) | Mid. (06, 19) |
| | Low (01, 01) | Low (04, 13) | Low (01, --) | Low (01, 09) |
| 4 (11, 12) | High (11, 23) | High (--, --) | High (19, 24) | High (04, 11) |
| | Mid. (11, 10) | Mid. (11, 12) | Mid. (08, 11) | Mid. (14, 17) |
| | Low (--, 01) | Low (05, 07) | Low (--, --) | Low (06, 04) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 102 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: D6. An electric circuit may be connected in series or in parallel.

Test Item Generalization: 27. If it is a closed circuit and electricity moves along a single path, then it is a series circuit.

B-31

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (19, 27) | High (24, 38) | High (16, 34) | High (25, 33) | High (25, 29) |
| | Mid. (17, 25) | Mid. (23, 28) | Mid. (15, 29) | Mid. (16, 28) |
| | Low (14, 23) | Low (13, 29) | Low (21, --) | Low (11, 16) |
| 5 (16, 24) | High (23, 34) | High (14, 37) | High (19, 33) | High (16, 27) |
| | Mid. (16, 21) | Mid. (18, 24) | Mid. (14, 22) | Mid. (16, 24) |
| | Low (02, 10) | Low (13, 14) | Low (06, --) | Low (13, 19) |
| 4 (10, 15) | High (16, 27) | High (--, --) | High (19, 28) | High (08, 25) |
| | Mid. (09, 22) | Mid. (11, 19) | Mid. (07, 19) | Mid. (13, 17) |
| | Low (--, 01) | Low (05, 19) | Low (--, --) | Low (01, 06) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 103 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: D6. An electric circuit may be connected in series or in parallel.

Test Item Generalization: 28. If it is a closed circuit and electricity moves along two or more paths, then it is a parallel circuit.

B-32

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (10, 32) | High (09, 47) | High (09, 44) | High (11, 47) | High (08, 39) |
| | Mid. (09, 31) | Mid. (10, 36) | Mid. (10, 27) | Mid. (09, 32) |
| | Low (12, 23) | Low (09, 28) | Low (08, --) | Low (17, 18) |
| 5 (10, 31) | High (05, 47) | High (21, 48) | High (11, 49) | High (11, 24) |
| | Mid. (11, 26) | Mid. (08, 37) | Mid. (08, 27) | Mid. (10, 37) |
| | Low (11, 08) | Low (12, 15) | Low (19, --) | Low (08, 23) |
| 4 (10, 24) | High (26, 64) | High (--, --) | High (15, 48) | High (08, 18) |
| | Mid. (08, 24) | Mid. (07, 28) | Mid. (07, 24) | Mid. (11, 36) |
| | Low (--, 01) | Low (05, 14) | Low (--, --) | Low (06, 06) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 104 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: D6. An electric circuit may be connected in series or in parallel.

Test Item Generalization: 29. If it is a house or auto or Christmas tree lights, then it usually has a parallel circuit.

B-33

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (05, 11) | High (05, 16) | High (06, 10) | High (07, 04) |
| 6 (07, 11) | Mid. (09, 13) | Mid. (07, 11) | Mid. (08, 10) | Mid. (08, 14) |
| | Low (07, 10) | Low (08, 07) | Low (13, --) | Low (08, 13) |
| | High (07, 07) | High (10, 07) | High (09, 09) | High (02, 06) |
| 5 (11, 11) | Mid. (10, 10) | Mid. (07, 08) | Mid. (11, 12) | Mid. (12, 12) |
| | Low (14, 13) | Low (13, 16) | Low (06, --) | Low (24, 19) |
| | High (05, 01) | High (--, --) | High (08, 03) | High (08, 01) |
| 4 (12, 12) | Mid. (11, 10) | Mid. (15, 09) | Mid. (13, 16) | Mid. (12, 12) |
| | Low (--, 25) | Low (16, 14) | Low (--, --) | Low (13, 19) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 105 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: E1. Most metals are good conductors.

Test Item Generalization: 37. If it is metal, then it is usually a good conductor of electricity.

B-34

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (45, 59) | High (50, 79) | High (50, 70) | High (50, 70) | High (42, 56) |
|  | Mid. (47, 60) | Mid. (44, 65) | Mid. (38, 52) | Mid. (48, 68) |
|  | Low (37, 40) | Low (40, 47) | Low (46, --) | Low (28, 31) |
| 5 (47, 58) | High (55, 81) | High (48, 85) | High (58, 80) | High (47, 68) |
|  | Mid. (49, 60) | Mid. (50, 66) | Mid. (47, 61) | Mid. (52, 60) |
|  | Low (20, 33) | Low (41, 46) | Low (38, --) | Low (24, 34) |
| 4 (40, 47) | High (79, 82) | High (--, --) | High (65, 76) | High (54, 61) |
|  | Mid. (37, 49) | Mid. (37, 47) | Mid. (34, 40) | Mid. (44, 53) |
|  | Low (--, 25) | Low (34, 40) | Low (--, --) | Low (19, 29) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 106 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: E2. An electric current does not flow easily along poor conductors of electricity.

Test Item Generalization: 32. If it is a cotton, then it strongly resists the flow of electricity.

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (30, 41) | High (42, 69) | High (45, 68) | High (43, 57) | High (33, 45) |
| | Mid. (32, 42) | Mid. (31, 48) | Mid. (20, 36) | Mid. (31, 50) |
| | Low (17, 14) | Low (23, 28) | Low (08, --) | Low (08, 03) |
| 5 (21, 34) | High (35, 60) | High (41, 67) | High (30, 56) | High (21, 41) |
| | Mid. (19, 26) | Mid. (24, 36) | Mid. (22, 28) | Mid. (20, 32) |
| | Low (02, 10) | Low (13, 18) | Low (01, --) | Low (24, 23) |
| 4 (07, 17) | High (11, 41) | High (--, --) | High (12, 41) | High (08, 14) |
| | Mid. (07, 17) | Mid. (08, 22) | Mid. (05, 13) | Mid. (09, 25) |
| | Low (--, 01) | Low (03, 02) | Low (--, --) | Low (01, 02) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 107 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: E5. When an electric current flows along a wire, the wire is heated.

Test Item Generalization: 38. If wires are heated by the same amount of electric current, then the thickest wire has the lowest temperature.

| Grade Level | Information Known About Pupils | | | |
|---|---|---|---|---|
| | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (53, 56) | High (72, 84) | High (66, 80) | High (60, 73) | High (48, 52) |
| | Mid. (54, 55) | Mid. (61, 67) | Mid. (52, 56) | Mid. (59, 68) |
| | Low (33, 40) | Low (38, 42) | Low (33, --) | Low (33, 23) |
| 5 (39, 45) | High (55, 60) | High (41, 56) | High (53, 65) | High (38, 45) |
| | Mid. (33, 40) | Mid. (43, 51) | Mid. (37, 42) | Mid. (44, 50) |
| | Low (25, 26) | Low (28, 32) | Low (13, --) | Low (21, 26) |
| 4 (23, 34) | High (58, 64) | High (--, --) | High (35, 59) | High (42, 64) |
| | Mid. (18, 37) | Mid. (25, 41) | Mid. (18, 35) | Mid. (22, 33) |
| | Low (--, 13) | Low (13, 16) | Low (--, --) | Low (09, 17) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 108 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: E5. When an electric current flows along a wire, the wire is heated.

Test Item Generalization: 39. If wires are heated by the same amount of electric current, the narrowest wire is the highest temperature.

B-37

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (77, 86) | High (70, 84) | High (67, 76) | High (56, 57) |
| 6 (56, 59) | Mid. (55, 58) | Mid. (63, 70) | Mid. (55, 61) | Mid. (60, 70) |
| | Low (37, 37) | Low (39, 48) | Low (25, --) | Low (33, 21) |
| | High (59, 64) | High (45, 63) | High (57, 70) | High (38, 48) |
| 5 (40, 50) | Mid. (33, 43) | Mid. (43, 55) | Mid. (34, 43) | Mid. (46, 56) |
| | Low (20, 31) | Low (33, 34) | Low (19, --) | Low (21, 32) |
| | High (53, 64) | High (--, --) | High (46, 66) | High (60, 57) |
| 4 (28, 35) | Mid. (29, 42) | Mid. (32, 47) | Mid. (26, 39) | Mid. (26, 38) |
| | Low (--, 19) | Low (16, 16) | Low (--, --) | Low (16, 17) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 109 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: E6. In electrical heating appliances a current is sent along a wire which is a poor conductor.

Test Item Generalization: 35. If electricity is used to make heat, then a large current of electricity is needed.

B-38

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (06, 07) | High (02, 08) | High (04, 04) | High (03, 01) |
| 6 (03, 05) | Mid. (02, 06) | Mid. (03, 04) | Mid. (03, 04) | Mid. (03, 07) |
| | Low (01, 02) | Low (03, 04) | Low (04, --) | Low (08, 06) |
| | High (08, 07) | High (14, 07) | High (12, 09) | High (08, 06) |
| 5 (07, 05) | Mid. (04, 04) | Mid. (05, 05) | Mid. (06, 04) | Mid. (08, 05) |
| | Low (07, 03) | Low (04, 05) | Low (01, --) | Low (05, 04) |
| | High (05, 14) | High (--, --) | High (04, 10) | High (01, 04) |
| 4 (04, 06) | Mid. (05, 05) | Mid. (01, 07) | Mid. (05, 06) | Mid. (05, 06) |
| | Low (--, 06) | Low (08, 02) | Low (--, --) | Low (06, 08) |

*First numeral in parentheses indicates probable success before instruction (success on E12). Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 110 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: E6. In electrical heating appliances a current is sent along a wire which is a poor conductor.

Test Item Generalization: 36. If it is an electric motor, then it does not need heat made by electricity.

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (18, 18) | High (22, 27) | High (20, 26) | High (20, 24) | High (19, 18) |
| | Mid. (18, 17) | Mid. (21, 19) | Mid. (17, 17) | Mid. (17, 20) |
| | Low (14, 11) | Low (14, 17) | Low (08, --) | Low (19, 11) |
| 5 (11, 13) | High (19, 23) | High (24, 11) | High (14, 20) | High (04, 19) |
| | Mid. (07, 11) | Mid. (10, 17) | Mid. (10, 10) | Mid. (15, 12) |
| | Low (11, 01) | Low (07, 07) | Low (06, --) | Low (08, 04) |
| 4 (15, 13) | High (26, 27) | High (--, --) | High (19, 24) | High (25, 18) |
| | Mid. (15, 14) | Mid. (19, 15) | Mid. (13, 10) | Mid. (16, 16) |
| | Low (--, 06) | Low (03, 05) | Low (--, --) | Low (03, 04) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 111 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: E7. When a large electric current flows along a wire which is a poor conductor, it may become hot enough to give off light.

Test Item Generalization: 40. If wires are to be chosen for a light bulb, then the narrowest wire would be chosen.

B-40

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (40, 51) | High (32, 52) | High (34, 42) | High (31, 34) |
| 6 (31, 35) | Mid. (30, 34) | Mid. (38, 43) | Mid. (32, 36) | Mid. (34, 41) |
| | Low (17, 22) | Low (23, 22) | Low (17, --) | Low (17, 15) |
| | High (32, 43) | High (31, 37) | High (30, 43) | High (27, 24) |
| 5 (27, 32) | Mid. (27, 25) | Mid. (27, 39) | Mid. (28, 28) | Mid. (28, 37) |
| | Low (09, 28) | Low (27, 18) | Low (06, --) | Low (18, 28) |
| | High (32, 32) | High (--, --) | High (27, 31) | High (17, 14) |
| 4 (19, 21) | Mid. (18, 21) | Mid. (21, 23) | Mid. (18, 18) | Mid. (19, 26) |
| | Low (--, 13) | Low (13, 16) | Low (--, --) | Low (19, 13) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 112 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: F1. The chemical changes in an electric cell provide an excess of electrons at the negative terminal and few electrons at the positive terminal.
Test Item Generalization: 31. If a new material is made, then this is a chemical change.

B-41

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| 6 (27, 28) | High (46, 55) | High (45, 62) | High (34, 48) | High (25, 22) |
| | Mid. (20, 26) | Mid. (29, 30) | Mid. (24, 23) | Mid. (29, 36) |
| | Low (19, 12) | Low (18, 18) | Low (08, --) | Low (22, 13) |
| 5 (27, 23) | High (43, 39) | High (48, 52) | High (44, 42) | High (20, 14) |
| | Mid. (22, 19) | Mid. (32, 25) | Mid. (20, 16) | Mid. (33, 31) |
| | Low (09, 05) | Low (16, 16) | Low (06, --) | Low (16, 13) |
| 4 (17, 14) | High (32, 27) | High (--, --) | High (35, 17) | High (08, 11) |
| | Mid. (20, 14) | Mid. (12, 14) | Mid. (13, 19) | Mid. (22, 21) |
| | Low (--, 01) | Low (21, 16) | Low (--, --) | Low (09, 04) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 113 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

**Generalization**: F1. The chemical changes in an electric cell provide an excess of electrons at the negative terminal and few electrons at the positive terminal.

**Test Item Generalization**: 34. If it is a cell, then it uses a chemical change to make an excess of electrons.

B-42

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (16, 24) | High (14, 30) | High (15, 18) | High (10, 13) |
| 6 (11, 14) | Mid. (10, 13) | Mid. (12, 13) | Mid. (08, 10) | Mid. (11, 16) |
| | Low (07, 06) | Low (09, 12) | Low (04, --) | Low (14, 05) |
| | High (08, 16) | High (10, 19) | High (09, 18) | High (10, 13) |
| 5 (10, 12) | Mid. (08, 10) | Mid. (07, 11) | Mid. (09, 12) | Mid. (10, 12) |
| | Low (11, 08) | Low (12, 13) | Low (25, --) | Low (08, 13) |
| | High (16, 23) | High (--, --) | High (12, 21) | High (13, 04) |
| 4 (05, 06) | Mid. (02, 03) | Mid. (03, 03) | Mid. (02, 01) | Mid. (04, 08) |
| | Low (--, 01) | Low (03, 01) | Low (--, --) | Low (03, 02) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 114 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: F2. The increase of electrons at a terminal forms a force which moves electrons along a conductor.

Test Item Generalization: 33. If there is a large group of electrons, then they may push some electrons through a conductor.

B-43

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
|  | High (10, 26) | High (16, 32) | High (09, 23) | High (13, 18) |
| 6 (09, 16) | Mid. (10, 17) | Mid. (08, 15) | Mid. (08, 11) | Mid. (07, 15) |
|  | Low (06, 11) | Low (08, 14) | Low (13, --) | Low (06, 16) |
|  | High (11, 20) | High (07, 26) | High (09, 19) | High (07, 14) |
| 5 (09, 12) | Mid. (08, 06) | Mid. (10, 11) | Mid. (10, 10) | Mid. (10, 11) |
|  | Low (05, 08) | Low (06, 11) | Low (06, --) | Low (08, 09) |
|  | High (11, 23) | High (--, --) | High (08, 17) | High (17, 11) |
| 4 (08, 08) | Mid. (09, 06) | Mid. (10, 07) | Mid. (11, 09) | Mid. (08, 09) |
|  | Low (--, 01) | Low (05, 02) | Low (--, --) | Low (01, 02) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 115 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

**Generalization**: F3. Electrons from the negative terminal of a cell will readily flow along a conductor tending to equalize the number of electrons at each terminal.

**Test Item Generalization**: 44. If it is a dry cell, then electricity moves from the negative terminal to the positive terminal.

B-44

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (01, 06) | High (01, 08) | High (02,04) | High (03, 06) |
| 6 (03, 05) | Mid. (03, 05) | Mid. (02, 03) | Mid. (03,06) | Mid. (03, 05) |
| | Low (07, 04) | Low (07, 06) | Low (17,--) | Low (08, 06) |
| | High (01, 02) | High (01, 07) | High (03,04) | High (01, 02) |
| 5 (01, 04) | Mid. (02, 05) | Mid. (02, 05) | Mid. (01,06) | Mid. (02, 05) |
| | Low (01, 01) | Low (01, 04) | Low (01,--) | Low (01, 04) |
| | High (05, 05) | High (--, --) | High (01,03) | High (04, 11) |
| 4 (04, 06) | Mid. (02, 08) | Mid. (07, 08) | Mid. (05,13) | Mid. (02, 05) |
| | Low (--, 06) | Low (01, 07) | Low (--,--) | Low (06, 04) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 116 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: F3. Electrons from the negative terminal of a cell will readily flow along a conductor tending to equalize the number of electrons at each terminal.

Test Item Generalization: 43. If it is a flashlight cell, then electricity moves from the negative terminal to the positive terminal.

B-45

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (02, 10) | High (02, 12) | High (05, 06) | High (06, 08) |
| 6 (04, 06) | Mid. (05, 05) | Mid. (05, 06) | Mid. (04, 03) | Mid. (04, 05) |
| | Low (05, 02) | Low (04, 02) | Low (04, 01) | Low (01, 03) |
| | High (16, 06) | High (21, 11) | High (12, 08) | High (09, 11) |
| 5 (07, 07) | Mid. (03, 07) | Mid. (08, 05) | Mid. (06, 06) | Mid. (07, 05) |
| | Low (07, 05) | Low (05, 06) | Low (01, 08) | Low (03, 04) |
| | High (05, 05) | High (10, 09) | High (08, 10) | High (01, 07) |
| 4 (04, 06) | Mid. (02, 06) | Mid. (04, 11) | Mid. (03, 03) | Mid. (05, 08) |
| | Low (01, 06) | Low (03, 02) | Low (01, 01) | Low (03, 02) |

*First numeral in parentheses indicates probable success before instruction (success on E12). Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 117 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: F4. Since current produced by a cell flows in one direction only, it is called direct current.

Test Item Generalization: 47. If it is DC electricity, then it flows in one direction.

B-46

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| | High (09, 49) | High (18, 48) | High (10, 38) | High (08, 29) |
| 6 (07, 26) | Mid. (06, 21) | Mid. (05, 29) | Mid. (06, 26) | Mid. (07, 32) |
| | Low (04, 12) | Low (05, 20) | Low (04, --) | Low (03, 02) |
| | High (11, 40) | High (03, 52) | High (06, 35) | High (09, 31) |
| 5 (07, 23) | Mid. (07, 17) | Mid. (08, 25) | Mid. (08, 21) | Mid. (08, 24) |
| | Low (07, 05) | Low (06, 11) | Low (06, --) | Low (03, 06) |
| | High (05, 41) | High (--, --) | High (04, 41) | High (04, 39) |
| 4 (04, 13) | Mid. (05, 09) | Mid. (04, 09) | Mid. (03, 06) | Mid. (04, 13) |
| | Low (--, 01) | Low (03, 05) | Low (--, --) | Low (03, 01) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 118 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: F5. Alternating current flows in one direction and then in opposite direction.

Test Item Generalization: 50. If it is AC electricity, then it flows back and forth.

B-47

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (04, 15) | High (05, 26) | High (07, 28) | High (06, 21) | High (03, 16) |
| | Mid. (02, 14) | Mid. (03, 12) | Mid. (03, 13) | Mid. (03, 16) |
| | Low (02, 10) | Low (03, 17) | Low (01, --) | Low (08, 06) |
| 5 (05, 12) | High (08, 20) | High (01, 19) | High (04, 14) | High (06, 16) |
| | Mid. (05, 07) | Mid. (04, 08) | Mid. (06, 12) | Mid. (06, 12) |
| | Low (02, 13) | Low (07, 14) | Low (06, --) | Low (01, 04) |
| 4 (07, 09) | High (01, 09) | High (--, --) | High (01, 17) | High (01, 11) |
| | Mid. (09, 08) | Mid. (03, 05) | Mid. (07, 05) | Mid. (08, 05) |
| | Low (--, 13) | Low (16, 09) | Low (--, --) | Low (09, 13) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 119 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: F6. Electricity from a generator may be either direct current (DC) or alternating current (AC).

Test Item Generalization: 45. If it is an electric generator, then it may make AC and DC electricity.

B-48

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (12, 14) | High (14, 19) | High (16, 14) | High (12,18) | High (09, 08) |
| | Mid. (08, 13) | Mid. (12, 15) | Mid. (12,14) | Mid. (11, 19) |
| | Low (10, 10) | Low (08, 14) | Low (13,--) | Low (19, 10) |
| 5 (16, 26) | High (15, 33) | High (14, 26) | High (15,33) | High (16, 23) |
| | Mid. (17, 24) | Mid. (13, 26) | Mid. (18,24) | Mid. (17, 30) |
| | Low (02, 10) | Low (17, 12) | Low (06,--) | Low (11, 21) |
| 4 (14, 12) | High (16, 14) | High (--, --) | High (04,21) | High (21, 21) |
| | Mid. (11, 12) | Mid. (15, 15) | Mid. (18,13) | Mid. (11, 09) |
| | Low (--, 13) | Low (13, 12) | Low (--,--) | Low (16, 12) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 120 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: F7. Electric current may be used to: heat or cook, make light, send messages, and run machines.

Test Item Generalization: 23. If it is electrical energy, then it may be used to cook food or light a room or move cars.

B-49

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (50, 44) | High (59, 69) | High (57, 70) | High (61, 61) | High (52, 49) |
|  | Mid. (48, 41) | Mid. (56, 51) | Mid. (47, 39) | Mid. (50, 45) |
|  | Low (42, 28) | Low (41, 29) | Low (25, --) | Low (44, 27) |
| 5 (37, 44) | High (36, 58) | High (34, 44) | High (44, 55) | High (37, 37) |
|  | Mid. (38, 35) | Mid. (34, 45) | Mid. (31, 32) | Mid. (34, 47) |
|  | Low (32, 15) | Low (36, 28) | Low (25, --) | Low (47, 45) |
| 4 (36, 31) | High (53, 36) | High (--, --) | High (58, 52) | High (46, 32) |
|  | Mid. (34, 34) | Mid. (33, 38) | Mid. (33, 34) | Mid. (35, 32) |
|  | Low (--, 25) | Low (34, 19) | Low (--, --) | Low (28, 27) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 121 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: G1. Moving a solid conductor through a magnetic field will generate an electric current.

Test Item Generalization: 41. If a copper wire coil is moved over a bar magnet, then an electric current flows in the coil.

B-50

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (05, 11) | High (05, 12) | High (05, 09) | High (07, 11) |
| 6 (07, 08) | Mid. (08, 05) | Mid. (05, 07) | Mid. (08, 07) | Mid. (07, 07) |
| | Low (07, 11) | Low (10, 09) | Low (08, --) | Low (08, 05) |
| | High (04, 02) | High (03, 04) | High (05, 03) | High (03, 01) |
| 5 (05, 04) | Mid. (05, 06) | Mid. (04, 04) | Mid. (05, 05) | Mid. (08, 05) |
| | Low (02, 03) | Low (04, 07) | Low (06, --) | Low (01, 06) |
| | High (01, 14) | High (--, --) | High (01, 10) | High (04, 04) |
| 4 (04, 06) | Mid. (03, 05) | Mid. (04, 03) | Mid. (07, 03) | Mid. (06, 06) |
| | Low (--, 01) | Low (08, 05) | Low (--, --) | Low (01, 08) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 122 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: G1. Moving a solid conductor through a magnetic field will generate an electric current.

Test Item Generalization: 42. If it is a bar magnet, then the magnetic field is strongest at the ends.

B-51

| Grade Level | Information Known About Pupils | | | |
|---|---|---|---|---|
| | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (20, 14) | High (14, 10) | High (17, 15) | High (14, 13) |
| 6 (13, 12) | Mid. (10, 10) | Mid. (14, 14) | Mid. (10, 09) | Mid. (14, 13) |
| | Low (07, 10) | Low (11, 06) | Low (08, --) | Low (06, 05) |
| | High (07, 20) | High (14, 19) | High (13, 23) | High (09, 12) |
| 5 (09, 14) | Mid. (12, 12) | Mid. (10, 17) | Mid. (08, 12) | Mid. (10, 17) |
| | Low (05, 05) | Low (06, 07) | Low (06, --) | Low (08, 08) |
| | High (21, 09) | High (--, --) | High (15, 17) | High (04, 07) |
| 4 (05, 13) | Mid. (03, 15) | Mid. (07, 16) | Mid. (03, 15) | Mid. (06, 14) |
| | Low (--, 19) | Low (03, 09) | Low (--, --) | Low (03, 13) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 123 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: G3. An electromagnet consists of a piece of iron within a coil of wire, along which a current of electricity is sent.

Test Item Generalization: 48. If electricity flows through an insulated coil of wire, then an iron rod can be used with it to make a strong electromagnet.

B-52

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (16, 14) | High (15, 23) | High (20, 22) | High (12, 15) | High (15, 16) |
| | Mid. (12, 12) | Mid. (15, 16) | Mid. (17, 13) | Mid. (15, 14) |
| | Low (20, 08) | Low (15, 06) | Low (17, --) | Low (22, 08) |
| 5 (15, 15) | High (15, 20) | High (24, 15) | High (14, 17) | High (11, 11) |
| | Mid. (13, 13) | Mid. (13, 19) | Mid. (16, 18) | Mid. (16, 19) |
| | Low (16, 13) | Low (17, 14) | Low (01, --) | Low (16, 09) |
| 4 (15, 14) | High (16, 41) | High (--, --) | High (12, 28) | High (29, 25) |
| | Mid. (14, 10) | Mid. (07, 09) | Mid. (21, 11) | Mid. (13, 15) |
| | Low (--, 06) | Low (24, 09) | Low (--, --) | Low (09, 06) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 124 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

Generalization: G6. An electromagnet has considerable force only so long as the electric current is flowing.

Test Item Generalization: 49. If electricity is not passing through an electromagnet, then its force ends.

B-53

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (34, 36) | High (49, 57) | High (45, 58) | High (40, 48) | High (32, 39) |
| | Mid. (29, 28) | Mid. (40, 40) | Mid. (26, 30) | Mid. (35, 40) |
| | Low (22, 17) | Low (21, 18) | Low (21, --) | Low (22, 13) |
| 5 (29, 38) | High (40, 59) | High (41, 59) | High (40, 57) | High (28, 38) |
| | Mid. (26, 31) | Mid. (35, 43) | Mid. (26, 32) | Mid. (31, 41) |
| | Low (05, 18) | Low (12, 29) | Low (06, --) | Low (18, 26) |
| 4 (24, 28) | High (37, 50) | High (--, --) | High (31, 45) | High (13, 32) |
| | Mid. (25, 28) | Mid. (22, 22) | Mid. (28, 26) | Mid. (30, 33) |
| | Low (--, 06) | Low (24, 28) | Low (--, --) | Low (19, 15) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

Table 125 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT ELECTRICITY*

**Generalization:** G7. Electromagnets are important parts of electric motors.

**Test Item Generalization:** 46. If it is an electric motor, then it uses an electromagnet.

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| | High (31, 49) | High (32, 46) | High (26, 38) | High (25, 35) |
| 6 (22, 31) | Mid. (18, 28) | Mid. (21, 37) | Mid. (19, 26) | Mid. (21, 34) |
| | Low (15, 14) | Low (16, 17) | Low (21, --) | Low (17, 15) |
| | High (27, 46) | High (24, 37) | High (23, 31) | High (19, 29) |
| 5 (20, 29) | Mid. (17, 25) | Mid. (18, 34) | Mid. (21, 34) | Mid. (22, 34) |
| | Low (14, 21) | Low (19, 28) | Low (06, --) | Low (11, 11) |
| | High (21, 27) | High (--, --) | High (19, 21) | High (13, 11) |
| 4 (12, 16) | Mid. (11, 16) | Mid. (11, 20) | Mid. (13, 19) | Mid. (14, 21) |
| | Low (--, 06) | Low (08, 07) | Low (--, --) | Low (06, 08) |

*First numeral in parentheses indicates probable success before instruction (success on E12).
Second numeral in parentheses indicates probable success after instruction (success on E23).

## Appendix C-1

## LIST OF GENERALIZATIONS ABOUT HEAT WITH CORRESPONDING TEST ITEMS

### A. MATTER AND HEAT ENERGY

4. In a solid, molecules are held close together by mutual attraction. (Test Item 2)

5. In a liquid, molecules are able to flow past one another. (Test Item 3)

6. In a gas, molecules are relatively far apart. (Test Item 1)

7. Heat energy is the energy of motion of the molecules of a body. (Test Item 6)

8. The sun transfers a great deal of heat energy to earth. (Test Item 5)

9. Chemical changes, electricity, and friction are common sources of heat. (Test Item 7)

### B. MEASURING HEAT ENERGY--TEMPERATURE, THERMOMETERS

3. Temperature is a measure of average energy of the motion of molecules in a material. (Test Item 4)

4. Temperature is not a measure of total amount of heat in a material. (Test Items 8, 9)

7. The fluid in a thermometer indicates temperature changes by expanding when heated and contracting when cooled. (Test Item 50)

8. The Fahrenheit scale and Centigrade scale are two common ways of marking thermometers. (Test Items 10, 11, 35, 36, 37)

### C. EXPANSION AND CONTRACTION

1. Most matter expands when it is heated and contracts when it is cooled. (Test Items 26, 38)

2. Removing heat from water cause it to contract until 4°C and then water expands until 0°C. (Test Items 42, 43, 48)

3. Adding heat increases the speed of the molecules in a substance. (Test Items 13, 44)

4. A solid may be changed to a liquid or gas by adding heat energy. (Test Items 12, 16, 23, 40)

5. Removing heat from a substance will decrease the speed of the molecules. (Test Item 39)

6. Removing heat from a material will cool it. (Test Item 14)

8. Evaporation is an important way to cool something. (Test Items 17, 18)

## D. TRANSFER OF HEAT ENERGY

1. It is natural for heat to travel from a hot region to a cooler region. (Test Items 15, 31)

2. Although heat energy may change its form, it is never lost in moving from one form or place to another. (Test Item 20)

## E. TRANSFER OF HEAT ENERGY--CONDUCTION

1. Heat may be transferred by conduction, convection, or radiation. (Test Item 25)

2. In conduction, heat energy is transferred from one molecule to another. (Test Item 45)

4. Metals conduct heat better than liquids or gases. (Test Item 27)

5. There are some materials through which heat does not travel easily and they are poor conductors of heat or insulators. (Test Item 29)

6. Paper, water, air, and glass are often used as insulators. (Test Items 30, 33)

8. An insulator keeps most of the heat from moving into a cooler region. (Test Item 34)

## F. TRANSFER OF HEAT ENERGY--CONVECTION

1. Convection is the transfer of heat energy of molecules in moving currents of fluids. (Test Items 22, 24)

2. Convection currents in fluids are created when the lighter parts of a fluid are forced upward by cooler and heavier parts which gravity forces downward. (Test Items 28, 32)

5. Atmospheric circulation and ordinary ventilation depend upon convection currents. (Test Items 21, 46)

## G. TRANSFER OF HEAT ENERGY--RADIATION

1. Radiation is emitted by almost all materials. (Test Item 49)

3. Energy from the sun travels to earth by radiation. (Test Items 19, 47)

6. Dark objects absorb radiant energy. (Test Item 41)

Table 126 NUMBER OF PUPILS USED IN EACH GRADE GROUP AND WITH TEST VARIABLES TO ESTABLISH PROBABILITY ESTIMATES OF SUCCESS FOR GENERALIZATIONS ABOUT HEAT

C-4

| | | | Science Bkgd. | | Read. Comp. | | Intel. Quot. | | Soc-Econ. |
|---|---|---|---|---|---|---|---|---|---|
| | H12 H23 | | H12 H23 | | H12 H23 | | H12 H23 | | H12 H23 |
| | | High | (109, 90) | High | ( 60, 53) | High | (118, 115) | High | (131, 121) |
| Grade 6 | (438, 371) | Mid | (154, 147) | Mid | (174, 157) | Mid | (176, 141) | Mid | (260, 238) |
| | | Low | ( 87, 52) | Low | (132, 92) | Low | ( 24, 18) | Low | ( 49, --) |
| | H12 H23 | | H12 H23 | | H12 H23 | | H12 H23 | | H12 H23 |
| | | High | ( 95, 94) | High | ( 36, 37) | High | (103, 96) | High | (115, 109) |
| Grade 5 | (343, 312) | Mid | (132, 117) | Mid | (132, 127) | Mid | (144, 124) | Mid | (167, 158) |
| | | Low | ( 42, 37) | Low | ( 86, 76) | Low | ( --, --) | Low | ( 63, 47) |
| | H12 H23 | | H12 H23 | | H12 H23 | | H12 H23 | | H12 H23 |
| | | High | ( 20, 16) | High | ( --, --) | High | ( 27, 21) | High | ( 25, 17) |
| Grade 4 | (181, 140) | Mid | ( 89, 77) | Mid | ( 70, 60) | Mid | ( 72, 57) | Mid | (101, 92) |
| | | Low | ( 17, --) | Low | ( 47, 30) | Low | ( --, --) | Low | ( 57, 33) |

In grade 6, there were 438 pupils used to establish probability estimates for each generalization on the double precision test (H12) and 371 pupils were used for the (H23) test. Probability estimates are not reported for samples of 15 pupils or less.

Table 127 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: A4. In a solid, molecules are held close together by mutual attraction.

Test Item Generalization: 2. If an object is a solid, then its molecules are very close togather.

C-5

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (57, 79) | High (65, 85) | High (64, 77) | High (60, 74) |
| 6 (49, 65) | Mid. (53, 65) | Mid. (52, 68) | Mid. (45, 61) | Mid. (48, 61) |
| | Low (31, 50) | Low (41, 53) | Low (21, 39) | Low (18, --) |
| | High (47, 68) | High (44, 68) | High (50, 72) | High (42, 72) |
| 5 (42, 64) | Mid. (43, 61) | Mid. (48, 64) | Mid. (40, 60) | Mid. (45, 60) |
| | Low (24, 43) | Low (34, 50) | Low (--, --) | Low (35, 53) |
| | High (45, 75) | High (--, --) | High (41, 67) | High (28, 53) |
| 4 (31, 49) | Mid. (34, 53) | Mid. (37, 53) | Mid. (29, 49) | Mid. (40, 54) |
| | Low (18, --) | Low (21, 33) | Low (--, --) | Low (16, 27) |

*First numeral in parentheses indicates probable success before instruction (success on H12). Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 128 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: A5. In a liquid, molecules are able to flow past one another.

Test Item Generalization: (3) If an object is a liquid, then its molecules are not very close together.

C-6

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (27, 39) | High (34, 58) | High (40, 60) | High (35, 59) | High (27, 46) |
| | Mid. (29, 39) | Mid. (30, 45) | Mid. (21, 29) | Mid. (28, 36) |
| | Low (16, 23) | Low (20, 26) | Low (21, 17) | Low (22, --) |
| 5 (29, 34) | High (37, 39) | High (31, 41) | High (39, 42) | High (28, 44) |
| | Mid. (29, 33) | Mid. (31, 35) | Mid. (26, 28) | Mid. (29, 29) |
| | Low (21, 22) | Low (28, 28) | Low (--, --) | Low (30, 28) |
| 4 (17, 36) | High (30, 88) | High (--, --) | High (26, 71) | High (08, 41) |
| | Mid. (16, 35) | Mid. (14, 40) | Mid. (17, 37) | Mid. (22, 41) |
| | Low (24, --) | Low (17, 23) | Low (--, --) | Low (11, 15) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 129 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

**Generalization**: A6. In a gas, molecules are relatively far apart.

**Test Item Generalization**: 1. If an object is a gas, then its molecules are far apart.

C-7

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (28, 61) | High (38, 72) | High (33, 63) | High (36, 55) |
| 6 (21, 46) | Mid. (20, 45) | Mid. (21, 49) | Mid. (16, 38) | Mid. (16, 44) |
| | Low (15, 37) | Low (17, 35) | Low (04, 22) | Low (10, --) |
| | High (17, 52) | High (22, 51) | High (18, 56) | High (17, 59) |
| 5 (16, 48) | Mid. (14, 48) | Mid. (13, 50) | Mid. (15, 40) | Mid. (15, 40) |
| | Low (10, 29) | Low (15, 38) | Low (--, --) | Low (14, 47) |
| | High (05, 50) | High (--, --) | High (07, 48) | High (04, 24) |
| 4 (07, 31) | Mid. (08, 38) | Mid. (09, 40) | Mid. (08, 33) | Mid. (09, 40) |
| | Low (01, --) | Low (04, 13) | Low (--, --) | Low (04, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 130 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: A7. Heat energy is the energy of motion of the molecules of a body.

Test Item Generalization: 6. If heat energy is produced, then some molecules are moving.

C-8

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (11, 25) | High (18, 44) | High (23, 43) | High (15, 37) | High (12, 25) |
| | Mid. (07, 19) | Mid. (11, 30) | Mid. (08, 19) | Mid. (12, 22) |
| | Low (09, 13) | Low (05, 10) | Low (04, 06) | Low (04, --) |
| 5 (09, 17) | High (11, 26) | High (11, 30) | High (09, 28) | High (13, 25) |
| | Mid. (08, 17) | Mid. (08, 19) | Mid. (08, 15) | Mid. (06, 14) |
| | Low (05, 08) | Low (07, 14) | Low (--, --) | Low (10, 06) |
| 4 (06, 14) | High (15, 31) | High (--, --) | High (11, 29) | High (08, 24) |
| | Mid. (01, 14) | Mid. (01, 12) | Mid. (04, 14) | Mid. (04, 15) |
| | Low (06, --) | Low (06, 13) | Low (--, --) | Low (07, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 131 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: A8. The sun transfers a great deal of heat energy to earth.

Test Item Generalization: 5. If it is the sun, then most of the earth's heat energy comes from it.

C-9

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (77, 84) | High (89, 86) | High (97, 89) | High (86, 90) | High (77, 85) |
| | Mid. (82, 85) | Mid. (83, 89) | Mid. (77, 84) | Mid. (80, 84) |
| | Low (61, 88) | Low (69, 83) | Low (54, 61) | Low (61, --) |
| 5 (74, 79) | High (87, 82) | High (86, 84) | High (83, 89) | High (80, 83) |
| | Mid. (73, 83) | Mid. (77, 84) | Mid. (71, 81) | Mid. (73, 83) |
| | Low (48, 57) | Low (63, 71) | Low (--, --) | Low (63, 55) |
| 4 (55, 65) | High (75, 75) | High (--, --) | High (74, 76) | High (60, 65) |
| | Mid. (54, 68) | Mid. (56, 70) | Mid. (60, 67) | Mid. (55, 68) |
| | Low (47, --) | Low (47, 47) | Low (--, --) | Low (49, 51) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 132 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: A9. Chemical changes, electricity, and friction are common sources of heat.

Test Item Generalization: 7. If a motor is started or a lamp is lighted or a slide is used, then heat is produced.

C-10

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| | High (35, 47) | High (37, 43) | High (31, 45) | High (27, 33) |
| 6 (29, 38) | Mid. (31, 34) | Mid. (29, 39) | Mid. (26, 35) | Mid. (30, 42) |
| | Low (25, 38) | Low (28, 37) | Low (42, 28) | Low (35, --) |
| | High (37, 46) | High (42, 49) | High (35, 42) | High (33, 39) |
| 5 (33, 38) | Mid. (37, 35) | Mid. (32, 33) | Mid. (31, 33) | Mid. (29, 34) |
| | Low (10, 16) | Low (27, 33) | Low (--, --) | Low (44, 45) |
| | High (25, 19) | High (--, --) | High (26, 33) | High (12, 24) |
| 4 (24, 21) | Mid. (27, 27) | Mid. (26, 17) | Mid. (24, 21) | Mid. (29, 24) |
| | Low (12, --) | Low (21, 23) | Low (--, --) | Low (21, 12) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 133 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: B3. Temperature is a measure of average energy of the motion of molecules in a material.

Test Item Generalization: 4. If molecules are not present in a container, then it has no temperature.

C-11

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (26, 40) | High (28, 47) | High (25, 37) | High (19, 27) |
| 6 (17, 27) | Mid. (15, 23) | Mid. (17, 30) | Mid. (10, 18) | Mid. (18, 28) |
| | Low (10, 15) | Low (14, 11) | Low (04, 06) | Low (08, --) |
| | High (23, 30) | High (14, 19) | High (21, 27) | High (13, 24) |
| 5 (14, 20) | Mid. (06, 15) | Mid. (16, 23) | Mid. (06, 14) | Mid. (16, 18) |
| | Low (02, 08) | Low (03, 12) | Low (--, --) | Low (11, 17) |
| | High (15, 38) | High (--, --) | High (15, 38) | High (12, 17) |
| 4 (08, 14) | Mid. (10, 12) | Mid. (10, 17) | Mid. (10, 14) | Mid. (10, 16) |
| | Low (01, --) | Low (04, 10) | Low (--, --) | Low (04, 03) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 134 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

**Generalization**: B4. Temperature is not a measure of total amount of heat in a material.

**Test Item Generalization**: 8. If it is the sun's surface, then it's temperature is higher than a flaming match or volcano or ocean.

C-12

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (91, 90) | High (97, 91) | High (91, 92) | High (80, 87) |
| 6 (76, 81) | Mid. (79, 86) | Mid. (79, 87) | Mid. (69, 74) | Mid. (81, 80) |
| | Low (55, 63) | Low (64, 72) | Low (38, 67) | Low (37, --) |
| | High (88, 85) | High (75, 81) | High (83, 86) | High (72, 79) |
| 5 (68, 73) | Mid. (64, 74) | Mid. (78, 80) | Mid. (70, 72) | Mid. (74, 74) |
| | Low (36, 22) | Low (52, 49) | Low (--, --) | Low (44, 53) |
| | High (90, 75) | High (--, --) | High (81, 71) | High (76, 71) |
| 4 (55, 55) | Mid. (57, 58) | Mid. (57, 58) | Mid. (57, 51) | Mid. (62, 59) |
| | Low (59, --) | Low (49, 43) | Low (--, --) | Low (32, 33) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 135 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: B4. Temperature is not a measure of total amount of heat in a material.

Test Item Generalization: 9, If it is an ocean, then it has more heat energy than a volcano or jet airplane or match.

C-13

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (01, 06) | High (01, 08) | High (01, 04) | High (01, 03) |
| 6 (02, 03) | Mid. (01, 03) | Mid. (01, 03) | Mid. (01, 04) | Mid. (01, 03) |
| | Low (01, 02) | Low (01, 02) | Low (01, 06) | Low (02, --) |
| | High (01, 02) | High (01, 03) | High (01, 02) | High (01, 01) |
| 5 (01, 01) | Mid. (01, 01) | Mid. (01, 01) | Mid. (01, 01) | Mid. (01, 01) |
| | Low (01, 01) | Low (01, 01) | Low (--, --) | Low (01, 02) |
| | High (01, 01) | High (--, --) | High (01, 01) | High (01, 01) |
| 4 (01, 01) | Mid. (01, 03) | Mid. (01, 01) | Mid. (01, 01) | Mid. (01, 02) |
| | Low (01, --) | Low (01, 01) | Low (--, --) | Low (01, 01) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 136 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: B7. The fluid in a thermometer indicates temperature changes by expanding when heated and contracting when cooled.

Test Item Generalization: 50. If the red material rises in a thermometer, then heat was added.

C-14

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (72, 74) | High (77, 70) | High (67, 69) | High (56, 60) |
| 6 (53, 57) | Mid. (55, 56) | Mid. (57, 63) | Mid. (47, 50) | Mid. (58, 58) |
| | Low (32, 37) | Low (42, 41) | Low (29, 28) | Low (16, --) |
| | High (65, 67) | High (67, 65) | High (65, 70) | High (53, 60) |
| 5 (45, 50) | Mid. (42, 50) | Mid. (55, 58) | Mid. (37, 46) | Mid. (44, 45) |
| | Low (24, 27) | Low (30, 41) | Low (--, --) | Low (33, 43) |
| | High (50, 63) | High (--, --) | High (48, 62) | High (32, 35) |
| 4 (30, 35) | Mid. (33, 29) | Mid. (33, 40) | Mid. (29, 37) | Mid. (42, 42) |
| | Low (18, --) | Low (21, 10) | Low (--, --) | Low (09, 12) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 137 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: B8. The Fahrenheit scale and Centigrade scale are two common ways of marking thermometers.

Test Item Generalization: 10. If it is boiling water, then the temperature is greater than 90°C or 110°F.

C-15

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (18, 33) | High (21, 37) | High (30, 43) | High (26, 42) | High (21, 36) |
| | Mid. (17, 34) | Mid. (16, 37) | Mid. (14, 33) | Mid. (17, 33) |
| | Low (13, 23) | Low (16, 25) | Low (04, 17) | Low (14, --) |
| 5 (17, 30) | High (24, 41) | High (19, 46) | High (21, 40) | High (18, 32) |
| | Mid. (14, 31) | Mid. (17, 31) | Mid. (17, 26) | Mid. (17, 29) |
| | Low (14, 14) | Low (14, 24) | Low (--, --) | Low (13, 30) |
| 4 (13, 22) | High (35, 63) | High (--, --) | High (22, 38) | High (16, 24) |
| | Mid. (15, 17) | Mid. (17, 22) | Mid. (17, 21) | Mid. (11, 24) |
| | Low (01, --) | Low (09, 17) | Low (--, --) | Low (16, 15) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 138 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: B8. The Fahrenheit scale and Centigrade scale are two common ways of marking thermometers.

Test Item Generalization: 11. If it is ice water, then the temperature is $0^{\circ}C$.

C-16

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (06, 14) | High (07, 18) | High (13, 30) | High (08, 20) | High (04, 16) |
| | Mid. (06, 12) | Mid. (05, 13) | Mid. (05, 11) | Mid. (07, 14) |
| | Low (03, 06) | Low (03, 07) | Low (01, 06) | Low (04, --) |
| 5 (08, 12) | High (04, 18) | High (06, 24) | High (10, 22) | High (11, 17) |
| | Mid. (09, 09) | Mid. (05, 13) | Mid. (06, 07) | Mid. (07, 08) |
| | Low (17, 11) | Low (10, 05) | Low (--, --) | Low (03, 09) |
| 4 (05, 06) | High (15, 13) | High (--, --) | High (07, 10) | High (16, 01) |
| | Mid. (04, 06) | Mid. (04, 07) | Mid. (04, 07) | Mid. (05, 10) |
| | Low (01, --) | Low (02, 10) | Low (--, --) | Low (01, 01) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 139 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: B8. The Fahrenheit scale and Centigrade scale are two common ways of marking thermometers.

Test Item Generalization: 35. If it is ice water, then the temperature is about $32^{o}F$.

C-17

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (52, 59) | High (61, 73) | High (63, 77) | High (67, 71) | High (60, 63) |
| | Mid. (56, 58) | Mid. (61, 64) | Mid. (44, 55) | Mid. (53, 58) |
| | Low (41, 38) | Low (42, 40) | Low (38, 33) | Low (27, --) |
| 5 (42, 50) | High (61, 65) | High (56, 57) | High (57, 65) | High (39, 53) |
| | Mid. (32, 49) | Mid. (42, 56) | Mid. (37, 47) | Mid. (47, 52) |
| | Low (29, 19) | Low (34, 36) | Low (--, --) | Low (33, 34) |
| 4 (30, 31) | High (60, 50) | High (--, --) | High (52, 48) | High (28, 24) |
| | Mid. (30, 32) | Mid. (37, 33) | Mid. (26, 33) | Mid. (37, 38) |
| | Low (06, --) | Low (15, 20) | Low (--, --) | Low (18, 12) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 140 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: B8. The Fahrenheit scale and Centigrade scale are two common ways of marking thermometers.

Test Item Generalization: 36. If it is a healthy child, then its temperature is about 98°F.

C-18

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (50, 62) | High (62, 74) | High (73, 85) | High (69, 81) | High (59, 63) |
| | Mid. (56, 67) | Mid. (56, 66) | Mid. (45, 55) | Mid. (47, 62) |
| | Low (33, 44) | Low (39, 52) | Low (33, 50) | Low (39, --) |
| 5 (43, 54) | High (60, 65) | High (67, 76) | High (60, 76) | High (49, 64) |
| | Mid. (39, 57) | Mid. (47, 58) | Mid. (34, 46) | Mid. (44, 49) |
| | Low (26, 22) | Low (30, 41) | Low (--, --) | Low (29, 40) |
| 4 (31, 46) | High (70, 75) | High (--, --) | High (74, 76) | High (32, 35) |
| | Mid. (34, 49) | Mid. (39, 57) | Mid. (29, 54) | Mid. (39, 59) |
| | Low (06, --) | Low (19, 33) | Low (--, --) | Low (18, 15) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 141 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: B8. The Fahrenheit scale and Centigrade scale are two common ways of marking thermometers.

Test Item Generalization: 37. If it is boiling water, then the temperature is about 212°F.

C-19

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (61, 74) | High (77, 91) | High (67, 89) | High (75, 92) | High (67, 79) |
|  | Mid. (64, 78) | Mid. (70, 84) | Mid. (59, 69) | Mid. (63, 73) |
|  | Low (46, 50) | Low (54, 58) | Low (25, 39) | Low (29, --) |
| 5 (59, 63) | High (75, 78) | High (72, 81) | High (78, 81) | High (68, 64) |
|  | Mid. (52, 57) | Mid. (65, 67) | Mid. (53, 55) | Mid. (57, 67) |
|  | Low (36, 27) | Low (42, 45) | Low (--, --) | Low (44, 43) |
| 4 (41, 41) | High (70, 75) | High (--, --) | High (70, 57) | High (48, 59) |
|  | Mid. (42, 43) | Mid. (44, 50) | Mid. (36, 46) | Mid. (49, 48) |
|  | Low (18, --) | Low (26, 23) | Low (--, --) | Low (23, 12) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 142 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

**Generalization**: C1. Most matter expands when it is heated and contracts when it is cooled.

**Test Item Generalization**: 26. If water is heated in a pan, then the pan is expanding.

C-20

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (21, 32) | High (23, 41) | High (23, 45) | High (23, 40) | High (24, 33) |
|  | Mid. (16, 28) | Mid. (20, 31) | Mid. (20, 25) | Mid. (22, 32) |
|  | Low (21, 27) | Low (19, 23) | Low (17, 39) | Low (06, --) |
| 5 (18, 33) | High (22, 43) | High (19, 41) | High (26, 43) | High (22, 29) |
|  | Mid. (18, 31) | Mid. (18, 35) | Mid. (12, 29) | Mid. (16, 37) |
|  | Low (10, 22) | Low (15, 29) | Low (--, --) | Low (19, 28) |
| 4 (16, 24) | High (25, 56) | High (--, --) | High (15, 48) | High (01, 24) |
|  | Mid. (13, 22) | Mid. (17, 22) | Mid. (15, 21) | Mid. (23, 26) |
|  | Low (06, --) | Low (11, 17) | Low (--, --) | Low (11, 15) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 143 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: Cl. Most matter expands when it is heated and contracts when it is cooled.

Test Item Generalization: 38. If the balloon has warm air and it is cooled, then the balloon becomes smaller.

C-21

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (41, 69) | High (43, 79) | High (41, 65) | High (40, 53) |
| 6 (39, 56) | Mid. (41, 54) | Mid. (40, 55) | Mid. (43, 50) | Mid. (41, 59) |
| | Low (36, 42) | Low (36, 48) | Low (33, 56) | Low (29, --) |
| | High (54, 56) | High (56, 59) | High (50, 66) | High (49, 54) |
| 5 (49, 55) | Mid. (49, 60) | Mid. (52, 58) | Mid. (53, 58) | Mid. (53, 61) |
| | Low (33, 49) | Low (44, 51) | Low (--, --) | Low (37, 38) |
| | High (55, 69) | High (--, --) | High (56, 62) | High (48, 41) |
| 4 (41, 51) | Mid. (48, 53) | Mid. (44, 60) | Mid. (42, 61) | Mid. (49, 61) |
| | Low (41, --) | Low (36, 33) | Low (--, --) | Low (23, 24) |

*First numeral in parentheses indicates probable success before instruction (success on H12). Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 144 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

**Generalization**: C2. Removing heat from water cause it to contract until 4°C and then water expands until 0°C.

**Test Item Generalization**: 42. If three containers are same size and hold ice or water or water vapor, then the water weighs most.

C-22

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (07, 09) | High (06, 11) | High (03, 09) | High (08, 11) | High (08, 14) |
| | Mid. (07, 10) | Mid. (07, 10) | Mid. (06, 06) | Mid. (07, 08) |
| | Low (02, 04) | Low (05, 05) | Low (01, 06) | Low (06, --) |
| 5 (04, 05) | High (04, 03) | High (06, 01) | High (05, 06) | High (06, 05) |
| | Mid. (05, 06) | Mid. (04, 06) | Mid. (04, 04) | Mid. (02, 04) |
| | Low (02, 03) | Low (03, 03) | Low (--, --) | Low (05, 09) |
| 4 (03, 05) | High (10, 13) | High (--, --) | High (07, 05) | High (01, 06) |
| | Mid. (02, 05) | Mid. (01, 05) | Mid. (03, 04) | Mid. (04, 05) |
| | Low (01, --) | Low (02, 01) | Low (--, --) | Low (02, 03) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 145 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: C2. Removing heat from water cause it to contract until 4°C and then water expands until 0°C.

Test Item Generalization: 43. If three containers are same size and hold ice or water or water vapor, then the water container has the most molecules.

C-23

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (02, 03) | High (01, 03) | High (01, 02) | High (02, 03) | High (03, 03) |
| | Mid. (03, 01) | Mid. (01, 01) | Mid. (02, 03) | Mid. (01, 03) |
| | Low (02, 08) | Low (04, 08) | Low (08, 11) | Low (06, --) |
| 5 (03, 03) | High (03, 05) | High (01, 01) | High (03, 03) | High (03, 03) |
| | Mid. (03, 01) | Mid. (06, 06) | Mid. (04, 04) | Mid. (03, 03) |
| | Low (05, 08) | Low (02, 03) | Low (--, --) | Low (05, 02) |
| 4 (02, 04) | High (01, 01) | High (--, --) | High (01, 01) | High (01, 01) |
| | Mid. (04, 04) | Mid. (01, 02) | Mid. (01, 04) | Mid. (02, 04) |
| | Low (01, --) | Low (04, 07) | Low (--, --) | Low (04, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 146 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

**Generalization**: C2. Removing heat from water causes it to contract until 4°C and then water expands until 0°C.

**Test Item Generalization**: 48. If ice floats on water, then this is because it has expanded upon freezing.

C-24

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| | High (03, 02) | High (03, 04) | High (05, 04) | High (05, 05) |
| 6 (05, 05) | Mid. (05, 06) | Mid. (04, 03) | Mid. (05, 05) | Mid. (05, 05) |
| | Low (08, 08) | Low (08, 10) | Low (04, 11) | Low (04, --) |
| | High (05, 01) | High (06, 05) | High (08, 01) | High (07, 01) |
| 5 (06, 04) | Mid. (07, 04) | Mid. (06, 02) | Mid. (06, 08) | Mid. (05, 05) |
| | Low (07, 11) | Low (07, 08) | Low (--, --) | Low (05, 09) |
| | High (15, 06) | High (--, --) | High (11, 05) | High (12, 01) |
| 4 (08, 09) | Mid. (04, 09) | Mid. (10, 05) | Mid. (04, 09) | Mid. (08, 11) |
| | Low (06, --) | Low (01, 13) | Low (--, --) | Low (05, 09) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 147 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

**Generalization**: C3. Adding heat increases the speed of the molecules in a substance.

**Test Item Generalization**: 13. If ice water is heated, then its molecules move faster.

C-25

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (36, 59) | High (49, 68) | High (53, 79) | High (49, 76) | High (41, 65) |
| | Mid. (32, 56) | Mid. (37, 59) | Mid. (31, 51) | Mid. (38, 58) |
| | Low (20, 48) | Low (23, 51) | Low (04, 44) | Low (06, --) |
| 5 (31, 44) | High (44, 55) | High (31, 46) | High (41, 53) | High (23, 44) |
| | Mid. (26, 35) | Mid. (36, 46) | Mid. (31, 39) | Mid. (40, 46) |
| | Low (05, 16) | Low (24, 37) | Low (--, --) | Low (21, 34) |
| 4 (14, 36) | High (15, 31) | High (--, --) | High (15, 48) | High (08, 12) |
| | Mid. (13, 38) | Mid. (17, 42) | Mid. (17, 28) | Mid. (18, 46) |
| | Low (06, --) | Low (13, 27) | Low (--, --) | Low (11, 21) |

*First numeral in parentheses indicates probable success before instruction (success on H12). Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 148 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: C3. Adding heat increases the speed of the molecules in a substance.

Test Item Generalization: 44. If three containers are same size and hold ice or water or water vapor, then a single water vapor molecule has the most energy.

C-26

| Grade Level | Information Known About Pupils | | | |
|---|---|---|---|---|
| | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (15, 18) | High (18, 23) | High (13, 17) | High (12, 16) | High (14, 18) |
| | Mid. (15, 17) | Mid. (13, 20) | Mid. (16, 16) | Mid. (15, 19) |
| | Low (11, 10) | Low (19, 11) | Low (21, 11) | Low (12, --) |
| 5 (15, 20) | High (21, 29) | High (17, 24) | High (18, 25) | High (17, 17) |
| | Mid. (11, 17) | Mid. (17, 22) | Mid. (15, 18) | Mid. (16, 23) |
| | Low (10, 03) | Low (09, 14) | Low (--, --) | Low (10, 17) |
| 4 (17, 14) | High (30, 13) | High (--, --) | High (30, 10) | High (24, 18) |
| | Mid. (16, 17) | Mid. (16, 22) | Mid. (17, 23) | Mid. (16, 16) |
| | Low (24, --) | Low (17, 13) | Low (--, --) | Low (14, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 149 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: C4. A solid may be changed to a liquid or gas by adding heat energy.

Test Item Generalization: 12. If ice water is heated, then the ice melts first.

C-27

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (75, 78) | High (83, 84) | High (85, 89) | High (82, 89) | High (77, 79) |
| | Mid. (79, 82) | Mid. (80, 82) | Mid. (74, 71) | Mid. (78, 79) |
| | Low (61, 63) | Low (65, 67) | Low (54, 72) | Low (53, --) |
| 5 (82, 83) | High (91, 87) | High (86, 84) | High (89, 89) | High (83, 82) |
| | Mid. (82, 81) | Mid. (89, 89) | Mid. (79, 84) | Mid. (86, 86) |
| | Low (69, 73) | Low (79, 76) | Low (--, --) | Low (67, 70) |
| 4 (64, 61) | High (85, 87) | High (--, --) | High (85, 81) | High (64, 59) |
| | Mid. (64, 61) | Mid. (73, 70) | Mid. (65, 54) | Mid. (71, 68) |
| | Low (53, --) | Low (55, 43) | Low (--, --) | Low (47, 36) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

5

Table 150 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: C4. A solid may be changed to a liquid or gas by adding heat energy.

Test Item Generalization: 16. If puddles of water are in sunlight, then the puddles change to gas.

C-28

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (34, 61) | High (50, 82) | High (58, 77) | High (54, 78) | High (45, 64) |
| | Mid. (31, 59) | Mid. (36, 66) | Mid. (27, 50) | Mid. (33, 61) |
| | Low (16, 33) | Low (25, 42) | Low (08, 39) | Low (04, --) |
| 5 (26, 50) | High (43, 63) | High (39, 65) | High (35, 57) | High (23, 49) |
| | Mid. (15, 46) | Mid. (20, 51) | Mid. (20, 52) | Mid. (29, 53) |
| | Low (05, 14) | Low (16, 33) | Low (--, --) | Low (21, 40) |
| 4 (13, 36) | High (30, 75) | High (--, --) | High (33, 62) | High (16, 41) |
| | Mid. (13, 34) | Mid. (16, 45) | Mid. (14, 35) | Mid. (18, 47) |
| | Low (01, --) | Low (06, 10) | Low (--, --) | Low (04, 03) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 151 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: C4. A solid may be changed to a liquid or gas by adding heat energy.

Test Item Generalization: 23. If hot dogs are cooking and you see grease dripping, then a liquid has formed.

C-29

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (68, 70) | High (68, 79) | High (67, 70) | High (63, 69) |
| 6 (53, 60) | Mid. (58, 68) | Mid. (59, 66) | Mid. (45, 58) | Mid. (52, 55) |
| | Low (34, 40) | Low (39, 47) | Low (33, 39) | Low (27, --) |
| | High (63, 73) | High (67, 70) | High (64, 69) | High (57, 61) |
| 5 (51, 55) | Mid. (52, 49) | Mid. (58, 60) | Mid. (47, 50) | Mid. (49, 53) |
| | Low (14, 24) | Low (34, 41) | Low (--, --) | Low (44, 49) |
| | High (65, 50) | High (--, --) | High (63, 67) | High (52, 18) |
| 4 (41, 42) | Mid. (44, 45) | Mid. (46, 43) | Mid. (40, 39) | Mid. (50, 51) |
| | Low (41, --) | Low (32, 27) | Low (--, --) | Low (21, 27) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 152 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: C4. A solid may be changed to a liquid or gas by adding heat energy.

Test Item Generalization: 40. If a snowman melts in the sunshine, then heat from the sun's rays caused the melting.

C-30

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (55, 59) | High (75, 73) | High (75, 68) | High (72, 77) | High (65, 63) |
| | Mid. (56, 61) | Mid. (61, 64) | Mid. (51, 52) | Mid. (57, 58) |
| | Low (32, 40) | Low (42, 47) | Low (33, 39) | Low (18, --) |
| 5 (49, 50) | High (66, 63) | High (58, 57) | High (65, 69) | High (50, 50) |
| | Mid. (42, 44) | Mid. (55, 57) | Mid. (48, 46) | Mid. (55, 53) |
| | Low (26, 24) | Low (36, 32) | Low (--, --) | Low (30, 36) |
| 4 (38, 39) | High (75, 75) | High (--, --) | High (70, 62) | High (48, 47) |
| | Mid. (38, 39) | Mid. (39, 45) | Mid. (32, 39) | Mid. (47, 45) |
| | Low (24, --) | Low (30, 30) | Low (--, --) | Low (18, 18) |

*First numeral in parentheses indicates probable success before instruction (success on H12). Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 153 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

**Generalization**: C5. Removing heat from a substance will decrease the speed of the molecules.

**Test Item Generalization**: 39. If the air in the balloon is cooled, then air molecules lose heat energy.

C-31

| Grade Level | Information Known About Pupils | | | |
|---|---|---|---|---|
| | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (48, 70) | High (57, 72) | High (42, 66) | High (39, 55) |
| 6 (37, 55) | Mid. (33, 50) | Mid. (36, 56) | Mid. (39, 50) | Mid. (39, 56) |
| | Low (25, 40) | Low (27, 45) | Low (13, 33) | Low (16, --) |
| | High (48, 52) | High (36, 41) | High (57, 63) | High (39, 44) |
| 5 (43, 46) | Mid. (39, 44) | Mid. (45, 51) | Mid. (36, 40) | Mid. (46, 48) |
| | Low (31, 22) | Low (34, 32) | Low (--, --) | Low (40, 38) |
| | High (45, 75) | High (--, --) | High (52, 71) | High (36, 47) |
| 4 (28, 34) | Mid. (26, 32) | Mid. (24, 33) | Mid. (22, 32) | Mid. (30, 39) |
| | Low (18, --) | Low (21, 27) | Low (--, --) | Low (19, 12) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 154 **PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT***

**Generalization**: C6. Removing heat from a material will cool it.

**Test Item Generalization**: 14, If heat is removed from ice water, then its temperature falls.

C-32

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
|  | High (37, 47) | High (33, 45) | High (32, 43) | High (29, 36) |
| 6 (23, 28) | Mid. (17, 19) | Mid. (25, 29) | Mid. (15, 18) | Mid. (23, 26) |
|  | Low (14, 15) | Low (11, 15) | Low (04, 11) | Low (08, --) |
|  | High (27, 27) | High (22, 16) | High (29, 28) | High (22, 18) |
| 5 (19, 17) | Mid. (20, 15) | Mid. (22, 24) | Mid. (15, 12) | Mid. (17, 18) |
|  | Low (07, 08) | Low (17, 13) | Low (--, --) | Low (16, 11) |
|  | High (25, 19) | High (--, --) | High (26, 29) | High (20, 29) |
| 4 (10, 16) | Mid. (09, 14) | Mid. (09, 15) | Mid. (08, 11) | Mid. (12, 15) |
|  | Low (06, --) | Low (06, 10) | Low (--, --) | Low (04, 09) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 155 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: C8. Evaporation is an important way to cool something.

Test Item Generalization: 17. If clouds are formed, then sunshine and water and evaporation have helped form them.

C-33

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (17, 23) | High (25, 25) | High (16, 26) | High (18, 21) |
| 6 (13, 17) | Mid. (12, 12) | Mid. (13, 18) | Mid. (11, 12) | Mid. (11, 15) |
| | Low (08, 10) | Low (09, 08) | Low (04, 01) | Low (12, --) |
| | High (17, 18) | High (19, 19) | High (22, 21) | High (12, 13) |
| 5 (12, 13) | Mid. (09, 09) | Mid. (12, 11) | Mid. (06, 09) | Mid. (13, 13) |
| | Low (05, 05) | Low (06, 11) | Low (--, --) | Low (08, 11) |
| | High (15, 25) | High (--, --) | High (15, 19) | High (16, 18) |
| 4 (09, 08) | Mid. (09, 08) | Mid. (06, 08) | Mid. (11, 05) | Mid. (08, 07) |
| | Low (01, --) | Low (11, 03) | Low (--, --) | Low (07, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 156 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

**Generalization**: C8. Evaporation is an important way to cool something.

**Test Item Generalization**: 18. If the children are wet and running, then they feel cold because water evaporates from their bodies.

C-34

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| 6 (33, 43) | High (39, 52) | High (48, 60) | High (36, 56) | High (39, 49) |
| | Mid. (34, 45) | Mid. (35, 47) | Mid. (35, 42) | Mid. (32, 41) |
| | Low (22, 27) | Low (27, 33) | Low (13, 17) | Low (20, --) |
| 5 (30, 42) | High (35, 48) | High (31, 49) | High (34, 45) | High (38, 44) |
| | Mid. (29, 39) | Mid. (33, 46) | Mid. (26, 44) | Mid. (26, 42) |
| | Low (26, 35) | Low (20, 33) | Low (--, --) | Low (22, 36) |
| 4 (24, 30) | High (35, 56) | High (--, --) | High (26, 52) | High (28, 29) |
| | Mid. (25, 27) | Mid. (20, 33) | Mid. (29, 28) | Mid. (22, 32) |
| | Low (29, --) | Low (34, 27) | Low (--, --) | Low (25, 24) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 157 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: D1. It is natural for heat to travel from a hot region to a cooler region.

Test Item Generalization: 15. If cold water falls onto children, then water gains heat and children lose heat and children are cooled.

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (15, 14) | High (17, 19) | High (19, 21) | High (15, 17) |
| 6 (14, 15) | Mid. (12, 15) | Mid. (13, 13) | Mid. (13, 11) | Mid. (13, 13) |
| | Low (18, 12) | Low (14, 14) | Low (13, 17) | Low (14, --) |
| | High (18, 17) | High (14, 16) | High (21, 15) | High (13, 11) |
| 5 (15, 11) | Mid. (14, 07) | Mid. (14, 10) | Mid. (10, 09) | Mid. (16, 11) |
| | Low (02, 08) | Low (10, 08) | Low (--, --) | Low (13, 13) |
| | High (10, 13) | High (--, --) | High (15, 14) | High (12, 06) |
| 4 (08, 09) | Mid. (11, 12) | Mid. (09, 08) | Mid. (11, 05) | Mid. (11, 11) |
| | Low (01, --) | Low (09, 03) | Low (--, --) | Low (02, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 158 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: D1. It is natural for heat to travel from a hot region to a cooler region.

Test Item Generalization: 31. If a refrigerator is opened, then heat travels from the room into the refrigerator.

C-36

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (30, 33) | High (47, 48) | High (47, 51) | High (46, 45) | High (31, 34) |
| | Mid. (27, 27) | Mid. (36, 34) | Mid. (25, 23) | Mid. (33, 34) |
| | Low (20, 19) | Low (20, 18) | Low (13, 22) | Low (12, --) |
| 5 (25, 28) | High (39, 39) | High (44, 46) | High (35, 44) | High (29, 31) |
| | Mid. (19, 24) | Mid. (26, 31) | Mid. (23, 23) | Mid. (23, 29) |
| | Low (14, 16) | Low (13, 17) | Low (--, --) | Low (22, 15) |
| 4 (22, 19) | High (45, 63) | High (--, --) | High (52, 52) | High (28, 35) |
| | Mid. (16, 14) | Mid. (17, 23) | Mid. (11, 09) | Mid. (21, 21) |
| | Low (24, --) | Low (15, 03) | Low (--, --) | Low (19, 03) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 159 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: D2. Although heat energy may change its form, it is never lost in moving from one form or place to another.

Test Item Generalization: 20. If the earth receives radiant energy from the sun, then its form is changed.

C-37

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|  | High (08, 12) | High (20, 17) | High (12, 13) | High (11, 17) |
| 6 (06, 11) | Mid. (06, 11) | Mid. (04, 14) | Mid. (04, 12) | Mid. (05, 08) |
|  | Low (05, 12) | Low (05, 07) | Low (01, 01) | Low (02, --) |
|  | High (09, 10) | High (08, 14) | High (13, 07) | High (10, 09) |
| 5 (06, 05) | Mid. (08, 03) | Mid. (08, 04) | Mid. (03, 05) | Mid. (04, 02) |
|  | Low (02, 01) | Low (05, 01) | Low (--, --) | Low (05, 04) |
|  | High (05, 19) | High (--, --) | High (07, 14) | High (04, 12) |
| 4 (03, 04) | Mid. (01, 01) | Mid. (01, 05) | Mid. (03, 02) | Mid. (03, 03) |
|  | Low (06, --) | Low (02, 01) | Low (--, --) | Low (04, 01) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 160 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

**Generalization**: E1. Heat may be transferred by conduction, convection, or radiation.

**Test Item Generalization**: 25. If heat energy is moved, then it may be moved by radiation or conduction or convection.

C-38

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (16, 36) | High (22, 38) | High (17, 34) | High (12, 18) |
| 6 (14, 25) | Mid. (14, 24) | Mid. (15, 29) | Mid. (11, 21) | Mid. (15, 29) |
| | Low (11, 13) | Low (11, 12) | Low (17, 06) | Low (14, --) |
| | High (13, 20) | High (08, 22) | High (14, 15) | High (15, 11) |
| 5 (15, 15) | Mid. (17, 14) | Mid. (14, 14) | Mid. (15, 19) | Mid. (14, 18) |
| | Low (10, 14) | Low (16, 18) | Low (--, --) | Low (21, 15) |
| | High (05, 25) | High (--, --) | High (15, 38) | High (01, 06) |
| 4 (14, 20) | Mid. (16, 23) | Mid. (14, 12) | Mid. (11, 18) | Mid. (19, 24) |
| | Low (18, --) | Low (21, 33) | Low ( ) | Low (12, 15) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 161 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: E2. In conduction, heat energy is teansferred from one molecule to another.

Test Item Generalization: 45. If a finger is burned touching a match, then this is heat conduction.

C-39

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| | High (02, 12) | High (02, 19) | High (02, 10) | High (01, 03) |
| 6 (03, 06) | Mid. (01, 03) | Mid. (02, 04) | Mid. (02, 02) | Mid. (03, 08) |
| | Low (07, 06) | Low (03, 03) | Low (13, 01) | Low (04, --) |
| | High (04, 06) | High (06, 05) | High (03, 06) | High (06, 03) |
| 5 (04, 05) | Mid. (04, 03) | Mid. (05, 05) | Mid. (07, 04) | Mid. (04, 07) |
| | Low (07, 05) | Low (05, 07) | Low (--, --) | Low (02, 02) |
| | High (05, 25) | High ( --, -) | High (01, 14) | High (04, 12) |
| 4 (02, 06) | Mid. (02, 04) | Mid. (03, 05) | Mid. (01, 04) | Mid. (02, 05) |
| | Low (01, --) | Low (01, 01) | Low (--, --) | Low (01, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 162 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: E4. Metals conduct heat better than liquids or gases.

Test Item Generalization: 27. If food is to be cooked quickly in a pan, then the pan should be metal.

C-40

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (67, 74) | High (75, 83) | High (78, 85) | High (77, 83) | High (70, 74) |
| | Mid. (69, 78) | Mid. (71, 78) | Mid. (65, 72) | Mid. (68, 74) |
| | Low (59, 62) | Low (59, 64) | Low (46, 56) | Low (45, --) |
| 5 (64, 68) | High (75, 77) | High (75, 76) | High (82, 78) | High (62, 66) |
| | Mid. (62, 67) | Mid. (68, 72) | Mid. (58, 61) | Mid. (69, 71) |
| | Low (43, 41) | Low (51, 53) | Low (--, --) | Low (52, 57) |
| 4 (51, 54) | High (80, 81) | High (--, --) | High (74, 81) | High (56, 53) |
| | Mid. (53, 53) | Mid. (53, 55) | Mid. (51, 56) | Mid. (57, 58) |
| | Low (41, --) | Low (51, 60) | Low (--, --) | Low (35, 39) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 163 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: E5. There are some materials through which heat does not travel easily and they are poor conductors of heat or insulators.
Test Item Generalization: 29. If a cooking pan has a handle, then a wood handle would be more useful than aluminum, steel, copper.

C-41

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (65, 82) | High (67, 77) | High (58, 69) | High (44, 50) |
| 6 (45, 60) | Mid. (46, 58) | Mid. (49, 64) | Mid. (36, 60) | Mid. (52, 68) |
| | Low (22, 44) | Low (31, 48) | Low (21, 22) | Low (10, --) |
| | High (41, 68) | High (39, 70) | High (45, 71) | High (36, 54) |
| 5 (30, 47) | Mid. (29, 41) | Mid. (35, 54) | Mid. (27, 43) | Mid. (34, 52) |
| | Low (12, 14) | Low (16, 25) | Low (--, --) | Low (11, 13) |
| | High (40, 81) | High (--, --) | High (33, 52) | High (36, 53) |
| 4 (23, 40) | Mid. (27, 42) | Mid. (27, 43) | Mid. (24, 47) | Mid. (31, 48) |
| | Low (12, --) | Low (17, 27) | Low (--, --) | Low (04, 09) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 164 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: E6. Paper, water, air, and glass are often used as insulators.

Test Item Generalization: 30. If it is air or water, then it is a poor conductor of heat.

C-42

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (22, 34) | High (22, 43) | High (33, 49) | High (30, 44) | High (29, 41) |
| | Mid. (29, 36) | Mid. (18, 31) | Mid. (18, 30) | Mid. (21, 32) |
| | Low (11, 21) | Low (22, 30) | Low (13, 11) | Low (04, --) |
| 5 (19, 33) | High (26, 43) | High (31, 51) | High (24, 47) | High (28, 49) |
| | Mid. (20, 32) | Mid. (20, 38) | Mid. (17, 28) | Mid. (13, 25) |
| | Low (10, 19) | Low (15, 26) | Low (--, --) | Low (17, 21) |
| 4 (15, 23) | High (40, 44) | High (--, --) | High (30, 48) | High (32, 18) |
| | Mid. (13, 22) | Mid. (14, 25) | Mid. (11, 14) | Mid. (14, 25) |
| | Low (06, --) | Low (09, 13) | Low (--, --) | Low (09, 18) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 165 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: E6. Paper, water, air and glass are often used as insulators.

Test Item Generalization: 33. If it is glass or air or paper, then it is a good insulator.

C-43

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (03, 07) | High (01, 11) | High (01, 11) | High (02, 12) | High (03, 08) |
| | Mid. (03, 05) | Mid. (02, 06) | Mid. (05, 05) | Mid. (02, 07) |
| | Low (07, 06) | Low (07, 07) | Low (04, 01) | Low (10, --) |
| 5 (02, 07) | High (01, 09) | High (03, 11) | High (02, 07) | High (03, 11) |
| | Mid. (05, 08) | Mid. (02, 06) | Mid. (04, 08) | Mid. (02, 05) |
| | Low (01, 05) | Low (01, 09) | Low (--, --) | Low (03, 06) |
| 4 (04, 05) | High (01, 01) | High (--, --) | High (04, 05) | High (01, 06) |
| | Mid. (06, 08) | Mid. (04, 08) | Mid. (07, 04) | Mid. (04, 04) |
| | Low (06, --) | Low (06, 03) | Low (--, --) | Low (05, 06) |

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*First numeral in parentheses indicates probable success before instruction (success on H12). Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 166 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: E8. An insulator keeps most of the heat from moving into a cooler region.

Test Item Generalization: 34. If it is an insulator for a refrigerator, then it keeps heat from entering the refrigerator.

C-44

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (37, 49) | High (55, 68) | High (68, 79) | High (56, 64) | High (45, 54) |
| | Mid. (40, 48) | Mid. (39, 49) | Mid. (30, 40) | Mid. (38, 48) |
| | Low (16, 19) | Low (27, 35) | Low (25, 28) | Low (10, --) |
| 5 (27, 39) | High (44, 59) | High (39, 57) | High (47, 58) | High (30, 44) |
| | Mid. (21, 31) | Mid. (30, 42) | Mid. (22, 33) | Mid. (31, 41) |
| | Low (05, 16) | Low (16, 22) | Low (--, --) | Low (13, 19) |
| 4 (19, 25) | High (60, 63) | High (--, --) | High (59, 62) | High (24, 47) |
| | Mid. (12, 21) | Mid. (16, 30) | Mid. (15, 26) | Mid. (22, 27) |
| | Low (06, --) | Low (15, 13) | Low (--, --) | Low (11, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 167 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

**Generalization**: F1. Convection is the transfer of heat energy of molecules in moving currents of fluids.

**Test Item Generalization**: 22. If hot dogs are cooking and you smell them, then a gas has been formed.

C-45

|  | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|  | High (23, 33) | High (22, 43) | High (20, 38) | High (21, 34) |
| 6 (15, 26) | Mid. (12, 19) | Mid. (17, 23) | Mid. (12, 17) | Mid. (13, 23) |
|  | Low (10, 19) | Low (10, 22) | Low (08, 06) | Low (08, --) |
|  | High (19, 22) | High (14, 22) | High (14, 23) | High (08, 16) |
| 5 (13, 16) | Mid. (10, 12) | Mid. (15, 20) | Mid. (12, 15) | Mid. (20, 20) |
|  | Low (05, 11) | Low (09, 11) | Low (--, --) | Low (05, 04) |
|  | High (30, 38) | High (--, --) | High (19, 19) | High (08, 18) |
| 4 (14, 24) | Mid. (17, 22) | Mid. (16, 20) | Mid. (17, 28) | Mid. (18, 25) |
|  | Low (06, --) | Low (15, 27) | Low (--, --) | Low (11, 21) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 168 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: F1. Convection is the transfer of heat energy of molecules in moving currents of fluids.

Test Item Generalization: 24. If hot dogs are cooking and you smell them, then this is a result of convection.

C-46

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (04, 11) | High (05, 15) | High (02, 10) | High (02, 06) |
| 6 (03, 06) | Mid. (02, 05) | Mid. (03, 06) | Mid. (03, 04) | Mid. (04, 07) |
| | Low (05, 02) | Low (02, 02) | Low (04, 06) | Low (04, --) |
| | High (01, 04) | High (01, 01) | High (01, 04) | High (01, 05) |
| 5 (01, 04) | Mid. (02, 03) | Mid. (01, 05) | Mid. (01, 04) | Mid. (02, 04) |
| | Low (01, 03) | Low (01, 03) | Low (--, --) | Low (01, 01) |
| | High (01, 06) | High (--, --) | High (04, 10) | High (04, 01) |
| 4 (04, 05) | Mid. (04, 06) | Mid. (04, 03) | Mid. (01, 02) | Mid. (01, 05) |
| | Low (06, --) | Low (04, 13) | Low (--, --) | Low (09, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 169 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: F2. Convection currents in fluids are created when the lighter parts of a fluid are forced upward by cooler and heavier parts which gravity forces downward.

Test Item Generalization: 28. If a pan of water is heated, then the air above the pan is forced upward.

C-47

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (38, 46) | High (51, 70) | High (55, 74) | High (50, 61) | High (46, 49) |
| | Mid. (32, 41) | Mid. (41, 50) | Mid. (30, 37) | Mid. (39, 46) |
| | Low (24, 23) | Low (25, 25) | Low (17, 17) | Low (08, --) |
| 5 (30, 35) | High (47, 49) | High (39, 49) | High (44, 51) | High (34, 37) |
| | Mid. (27, 32) | Mid. (32, 49) | Mid. (27, 32) | Mid. (30, 37) |
| | Low (07, 11) | Low (19, 24) | Low (--, --) | Low (24, 23) |
| 4 (19, 22) | High (60, 63) | High (--, --) | High (44, 57) | High (24, 29) |
| | Mid. (10, 17) | Mid. (16, 22) | Mid. (10, 16) | Mid. (19, 26) |
| | Low (18, --) | Low (13, 07) | Low (--, --) | Low (18, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 170 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: F2. Convection currents in fluids are created when the lighter parts of a fluid are forced upward by cooler and heavier parts which gravity forces downward.

Test Item Generalization: 32. If a refrigerator is opened, then the cold air falls onto the floor.

C-48

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| 6 (04, 05) | High (06, 09) | High (03, 09) | High (06, 10) | High (04, 07) |
| | Mid. (03, 04) | Mid. (02, 03) | Mid. (01, 01) | Mid. (03, 05) |
| | Low (02, 01) | Low (04, 02) | Low (04, 01) | Low (06, --) |
| 5 (03, 03) | High (02, 05) | High (03, 03) | High (01, 01) | High (03, 02) |
| | Mid. (03, 01) | Mid. (02, 02) | Mid. (05, 04) | Mid. (04, 03) |
| | Low (03, 03) | Low (06, 04) | Low (--, --) | Low (02, 04) |
| 4 (02, 02) | High (01, 01) | High (--, --) | High (01, 01) | High (01, 01) |
| | Mid. (02, 03) | Mid. (01, 02) | Mid. (03, 02) | Mid. (02, 03) |
| | Low (01, --) | Low (01, 01) | Low (--, --) | Low (02, 01) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 171 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: F5. Atmospheric circulation and ordinary ventilation depend upon convection currents.

Test Item Generalization: 21. If it is weather or wind or house ventilation, then it depends upon convection.

C-49

| Grade Level | Information Known About Pupils<br>Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|---|---|---|---|---|
| 6 (06, 07) | High (08, 09) | High (08, 17) | High (07, 10) | High (07, 04) |
| | Mid. (05, 07) | Mid. (06, 06) | Mid. (07, 05) | Mid. (05, 09) |
| | Low (09, 06) | Low (05, 05) | Low (08, 06) | Low (10, --) |
| 5 (10, 10) | High (06, 11) | High (08, 05) | High (08, 07) | High (09, 08) |
| | Mid. (13, 06) | Mid. (06, 07) | Mid. (11, 11) | Mid. (09, 11) |
| | Low (02, 08) | Low (14, 14) | Low (--, --) | Low (16, 09) |
| 4 (09, 06) | High (01, 01) | High (--, --) | High (15, 05) | High (12, 06) |
| | Mid. (12, 09) | Mid. (11, 07) | Mid. (08, 07) | Mid. (11, 07) |
| | Low (12, --) | Low (13, 10) | Low (--, --) | Low (04, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 172 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: F5. Atmospheric circulation and ordinary ventilation depend upon convection currents.

Test Item Generalization: 46. If it is a heater for a home, then may use convection.

C-50

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (05, 15) | High (07, 31) | High (10, 43) | High (07, 27) | High (05, 13) |
| | Mid. (06, 10) | Mid. (05, 12) | Mid. (06, 08) | Mid. (05, 17) |
| | Low (01, 08) | Low (04, 07) | Low (--, --) | Low (04, --) |
| 5 (05, 09) | High (07, 17) | High (06, 16) | High (07, 13) | High (03, 14) |
| | Mid. (02, 04) | Mid. (05, 07) | Mid. (04, 07) | Mid. (05, 08) |
| | Low (07, 08) | Low (05, 07) | Low (--, --) | Low (10, 02) |
| 4 (06, 07) | High (01, 31) | High (--, --) | High (01, 19) | High (04, 06) |
| | Mid. (04, 04) | Mid. (03, 01) | Mid. (06, 07) | Mid. (03, 07) |
| | Low (35, --) | Low (15, 13) | Low (--, --) | Low (12, 09) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 173 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: G1. Radiation is emitted by almost all materials.

Test Item Generalization: 49. If it is a person or a light bulb or a car, then it gives off radiant energy.

C-51

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (11, 18) | High (08, 17) | High (14, 23) | High (14, 20) |
| 6 (13, 16) | Mid. (14, 16) | Mid. (16, 19) | Mid. (11, 10) | Mid. (11, 14) |
| | Low (15, 17) | Low (12, 12) | Low (08, 22) | Low (18, --) |
| | High (18, 24) | High (11, 11) | High (11, 17) | High (14, 24) |
| 5 (16, 17) | Mid. (13, 17) | Mid. (17, 20) | Mid. (17, 19) | Mid. (25, 12) |
| | Low (12, 05) | Low (15, 14) | Low (--, --) | Low (26, 19) |
| | High (01, 01) | High (--, --) | High (11, 14) | High (01, 06) |
| 4 (12, 10) | Mid. (18, 14) | Mid. (17, 13) | Mid. (17, 11) | Mid. (17, 12) |
| | Low (06, --) | Low (09, 10) | Low (--, --) | Low (09, 06) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 174 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: G3. Energy from the sun travels to earth by radiation.

Test Item Generalization: 19. If it is the sun, then it gives the most of the earth's radiant energy.

C-52

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| 6 (62, 71) | High (77, 87) | High (82, 89) | High (78, 83) | High (63, 71) |
| | Mid. (62, 67) | Mid. (64, 74) | Mid. (51, 60) | Mid. (67, 71) |
| | Low (39, 52) | Low (48, 57) | Low (46, 56) | Low (29, --) |
| 5 (59, 60) | High (65, 66) | High (58, 68) | High (63, 70) | High (61, 60) |
| | Mid. (55, 57) | Mid. (61, 63) | Mid. (54, 55) | Mid. (58, 63) |
| | Low (43, 35) | Low (50, 47) | Low (--, --) | Low (56, 49) |
| 4 (41, 48) | High (70, 75) | High (--, --) | High (56, 57) | High (60, 47) |
| | Mid. (45, 60) | Mid. (46, 58) | Mid. (47, 60) | Mid. (48, 55) |
| | Low (29, --) | Low (38, 47) | Low (--, --) | Low (21, 24) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 175 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: G3. Energy from the sun travels to earth by radiation.

Test Item Generalization: 47. If the sun sends heat to earth, then this is an example of radiation.

C-53

| | Information Known About Pupils | | | |
|---|---|---|---|---|
| Grade Level | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
| | High (44, 70) | High (60, 81) | High (40, 61) | High (29, 51) |
| 6 (27, 44) | Mid. (26, 41) | Mid. (29, 45) | Mid. (18, 36) | Mid. (31, 42) |
| | Low (11, 17) | Low (15, 27) | Low (17, 17) | Low (02, --) |
| | High (29, 41) | High (25, 38) | High (23, 41) | High (16, 27) |
| 5 (20, 30) | Mid. (19, 27) | Mid. (23, 28) | Mid. (21, 30) | Mid. (25, 36) |
| | Low (02, 14) | Low (14, 26) | Low (--, --) | Low (13, 17) |
| | High (45, 50) | High (--, --) | High (37, 38) | High (12, 12) |
| 4 (13, 14) | Mid. (07, 12) | Mid. (07, 15) | Mid. (07, 12) | Mid. (15, 20) |
| | Low (06, --) | Low (11, 07) | Low (--, --) | Low (09, 01) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

Table 176 PROBABILITY ESTIMATES OF PUPILS' UNDERSTANDING OF GENERALIZATIONS ABOUT HEAT*

Generalization: G6. Dark objects absorb radiant energy.

Test Item Generalization: 41. If a black hat, water, snow, and air are placed in daylight, then the hat will have the highest temperature.

C-54

| Grade Level | Information Known About Pupils |  |  |  |
|---|---|---|---|---|
|  | Science Bkgd. | Reading Comp. | Intel. Quotient | Soc-Econ. Level |
|  | High (18, 19) | High (15, 15) | High (14, 15) | High (09, 12) |
| 6 (11, 13) | Mid. (11, 14) | Mid. (14, 15) | Mid. (10, 12) | Mid. (13, 14) |
|  | Low (06, 08) | Low (07, 11) | Low (04, 06) | Low (06, --) |
|  | High (13, 12) | High (08, 11) | High (12, 13) | High (11, 10) |
| 5 (12, 09) | Mid. (14, 10) | Mid. (14, 10) | Mid. (14, 08) | Mid. (13, 08) |
|  | Low (02, 03) | Low (08, 08) | Low (--, --) | Low (10, 11) |
|  | High (10, 19) | High (--, --) | High (11, 14) | High (16, 18) |
| 4 (10, 12) | Mid. (11, 16) | Mid. (16, 13) | Mid. (18, 14) | Mid. (12, 11) |
|  | Low (12, --) | Low (13, 13) | Low (--, --) | Low (05, 12) |

*First numeral in parentheses indicates probable success before instruction (success on H12).
Second numeral in parentheses indicates probable success after instruction (success on H23).

## Appendix D-1

## Instructions for Using Confidence Belts in Appendix D to Estimate Probable Error of a Proportion

The first table at the front of Appendices A, B, or C indicates the number of pupils used to calculate the probability estimates which are cited in each of the remaining tables in the appendix. Each of the probability estimates is a percent or proportion which indicated the percent of youngsters in a given grade level who had demonstrated that they could understand a particular generalization before instruction and retain that understanding for three to five months after instruction had concluded. These were empirically derived estimates.

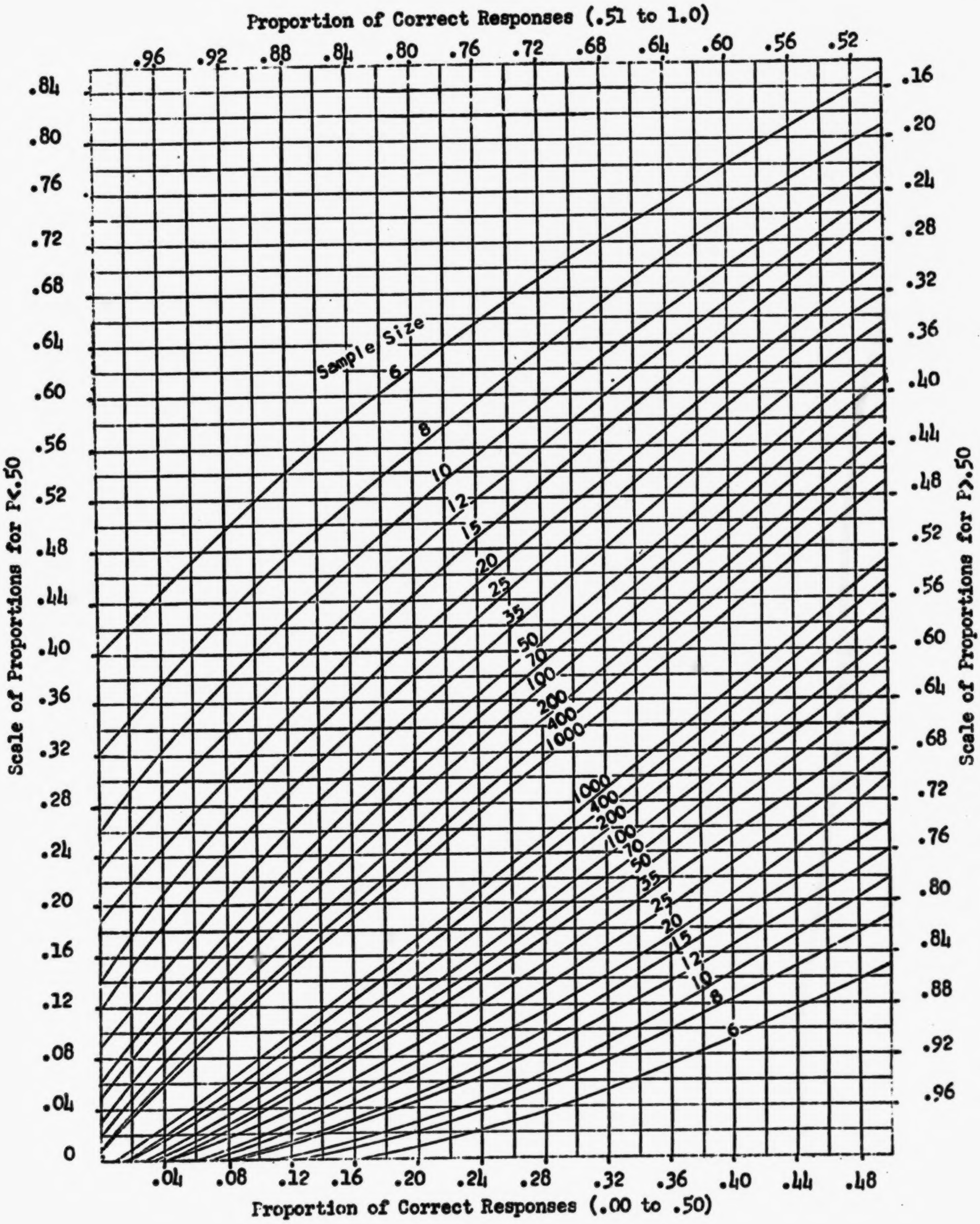
The graphs in Figure 9 provide a means of determining how accurate each of those percents or proportions may be. The vertical axis or ordinate on the left is arranged with an increasing scale from zero to 84% and it is appropriate to use with the percent estimates on the bottom axis which range from zero to 48%. The numbers on the vertical axis on the right start with 96% at the bottom and decrease to 16% at the top of the figure. They are to be used with the percent correct responses listed on the horizontal axis at the top of Figure 9 , which ranged from 52% to 96%.

The curves in the middle indicate the sample size used in estimating the range of accuracy. For example, suppose that a given proportion indicated the probable success before instruction was 26%. The first step in using the figure is to determine how many pupils were used in computing this estimate. Let us assume that 200 pupils were used in computing that estimate of 26%. Since the 26% is less than 50% the bottom horizontal axis would be used and the reader would find 26% on the bottom horizontal axis between 24% and 28%. Next, follow that 26% line upward until it crosses the curve indicated for a sample size of 200. At the point where the 26% line crosses the 200 sample size, trace the horizontal line to the left where the vertical axis indicates 20%. This indicates that the true proportion may drop as low as 20%. Continue to follow the vertical 26% line upward until it crosses the next curve in which the sample is also 200 and it indicates the upper limit of the proportion. The upper limit is between 32% and 34%. Therefore a rough estimate is that the proportion of 26% may range as high as 33%.

Here, then, are the limits of the proportion 26%. That proportion may range as high as 33% or it may drop as low as 20%. The reader may be confident that 90 times out of 100, the true proportion will range within that interval.

D-2

Figure 9 CONFIDENCE BELTS FOR PROPORTIONS (P) ESTIMATED FROM SAMPLE OF SIX OR MORE PUPILS (90% LEVEL OF CONFIDENCE)



*Reprinted from Nonparametric and Shortcut Statistics by Merle W. Tate and Richard C. Clelland by permission of Interstate Printers and Publishers, Inc., Danville, Ill. Copyrighted 1957.

## Appendix E-1

Total Responses: 88

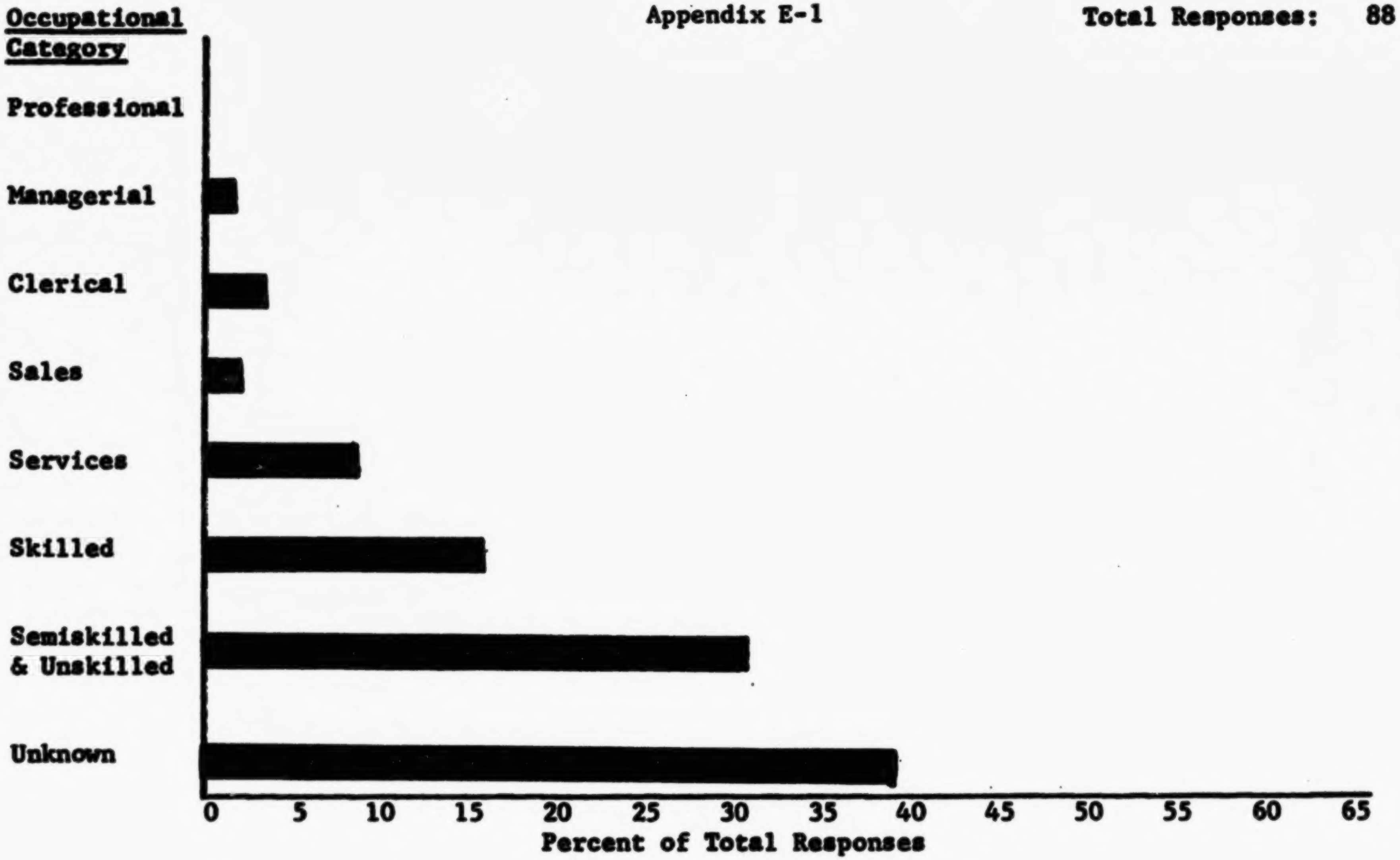


Figure 10 DISTRIBUTION OF OCCUPATIONS OF CHIEF WAGE EARNER IN SCHOOL #1 ACCORDING TO PUPILS' RESPONSES

## Appendix E-2

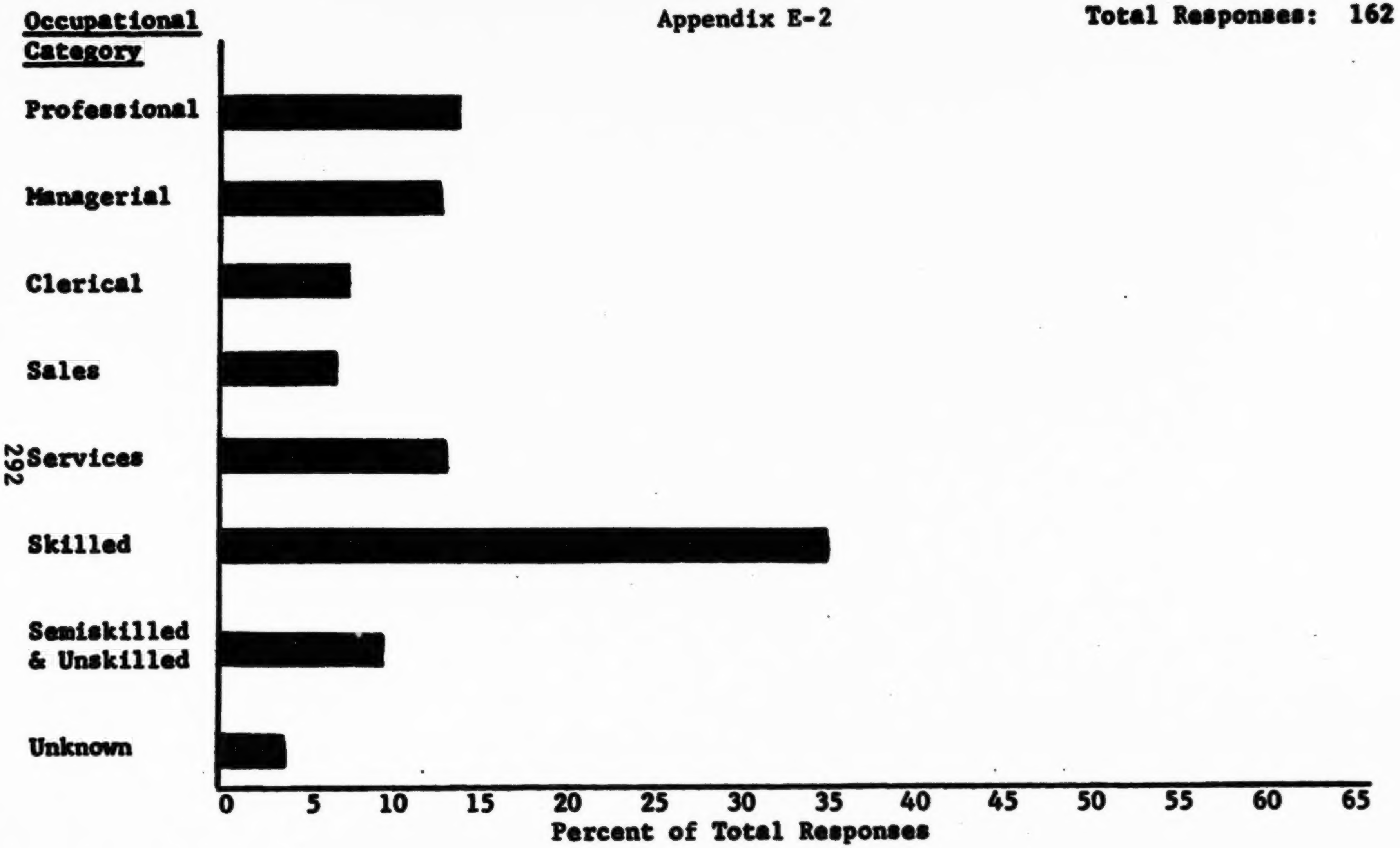


Figure 11 DISTRIBUTION OF OCCUPATIONS OF CHIEF WAGE EARNER IN SCHOOL #2 ACCORDING TO PUPILS' RESPONSES

## Appendix E-3

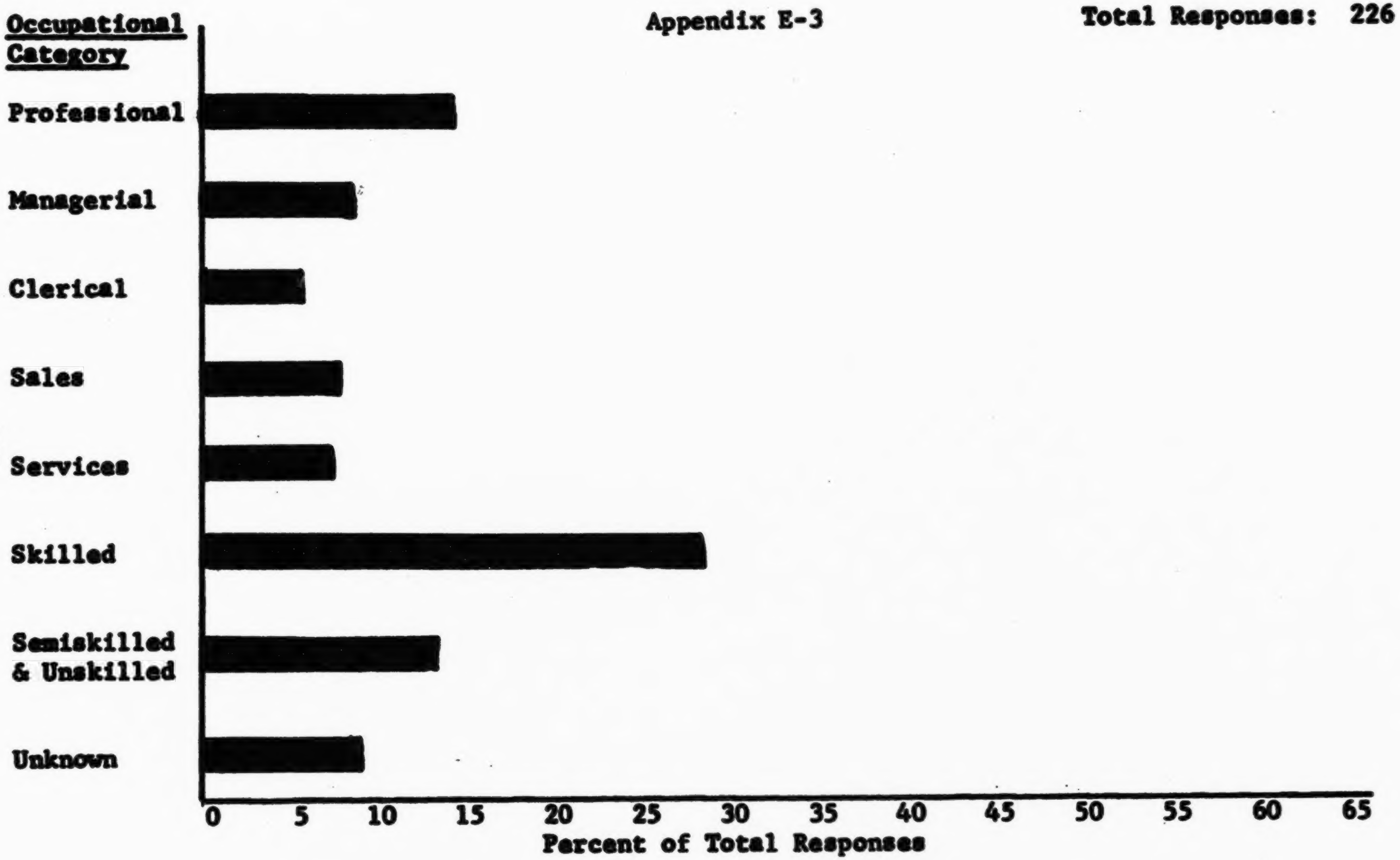


Figure 12 DISTRIBUTION OF OCCUPATIONS OF CHIEF WAGE EARNER IN SCHOOL #3 ACCORDING TO PUPILS' RESPONSES

# Appendix E4

Total Responses: 93

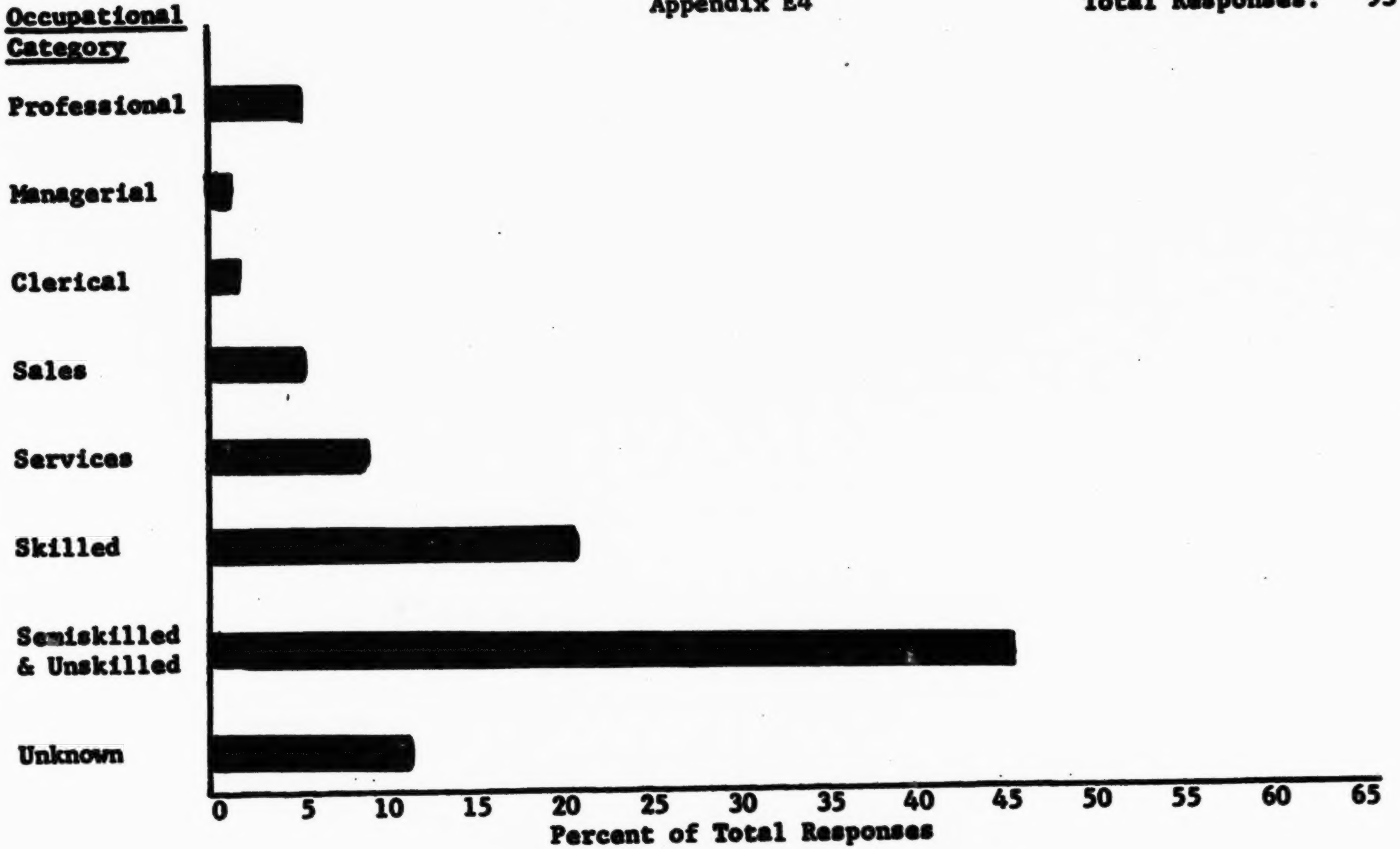


Figure 13 DISTRIBUTION OF OCCUPATIONS OF CHIEF WAGE EARNER IN SCHOOL #4 ACCORDING TO PUPILS' RESPONSES

## Appendix E-5

Total Responses: 218

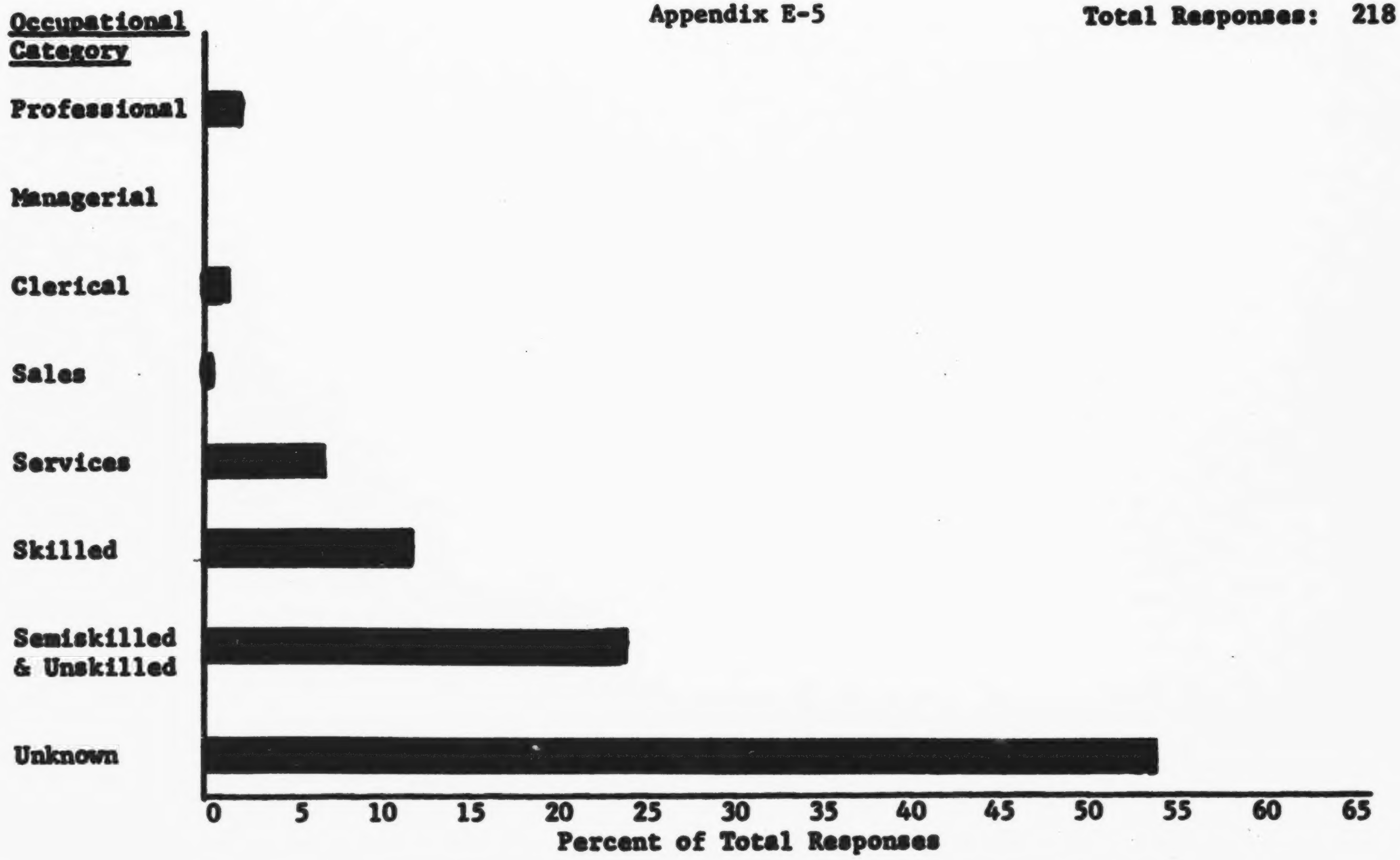


Figure 14 DISTRIBUTION OF OCCUPATIONS OF CHIEF WAGE EARNER IN SCHOOL #5 ACCORDING TO PUPILS' RESPONSES

## Appendix E-6

Total Responses: 161

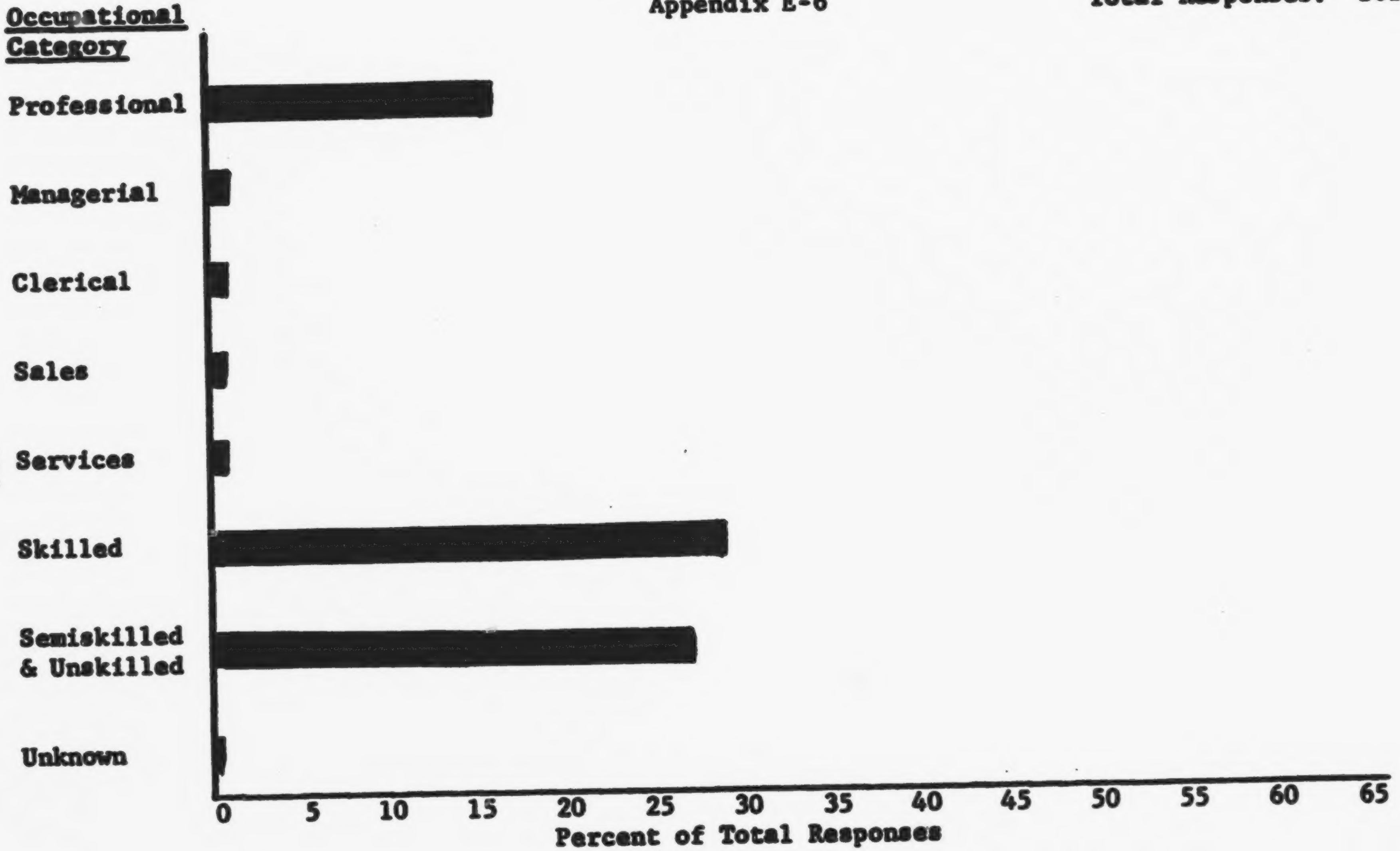


Figure 15 DISTRIBUTION OF OCCUPATIONS OF CHIEF WAGE EARNER IN SCHOOL #6 ACCORDING TO PUPILS' RESPONSES

## Appendix E-7

Total Responses: 185

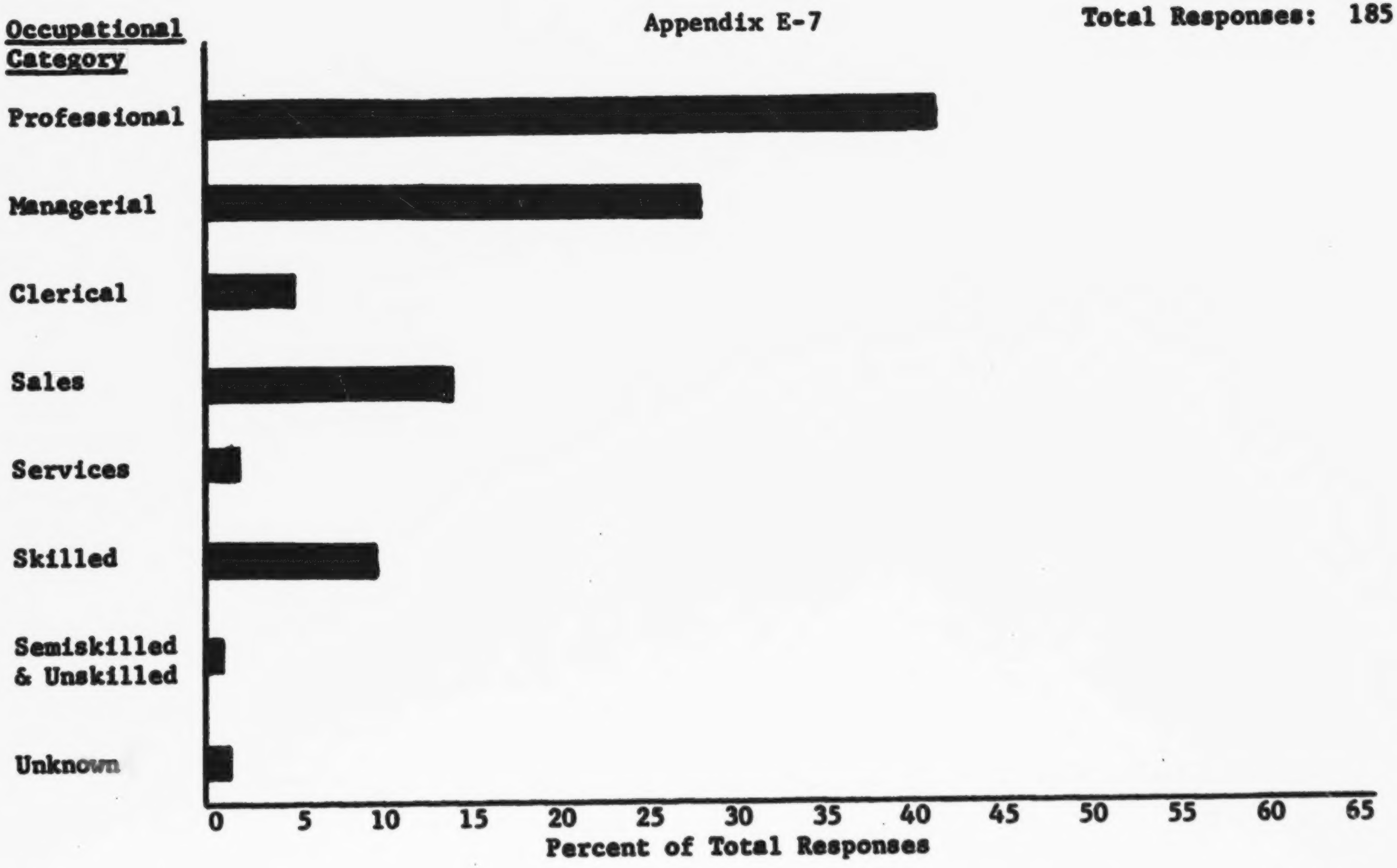


Figure 16 DISTRIBUTION OF OCCUPATIONS OF CHIEF WAGE EARNER IN SCHOOL #7 ACCORDING TO PUPILS' RESPONSES

## Appendix E-8

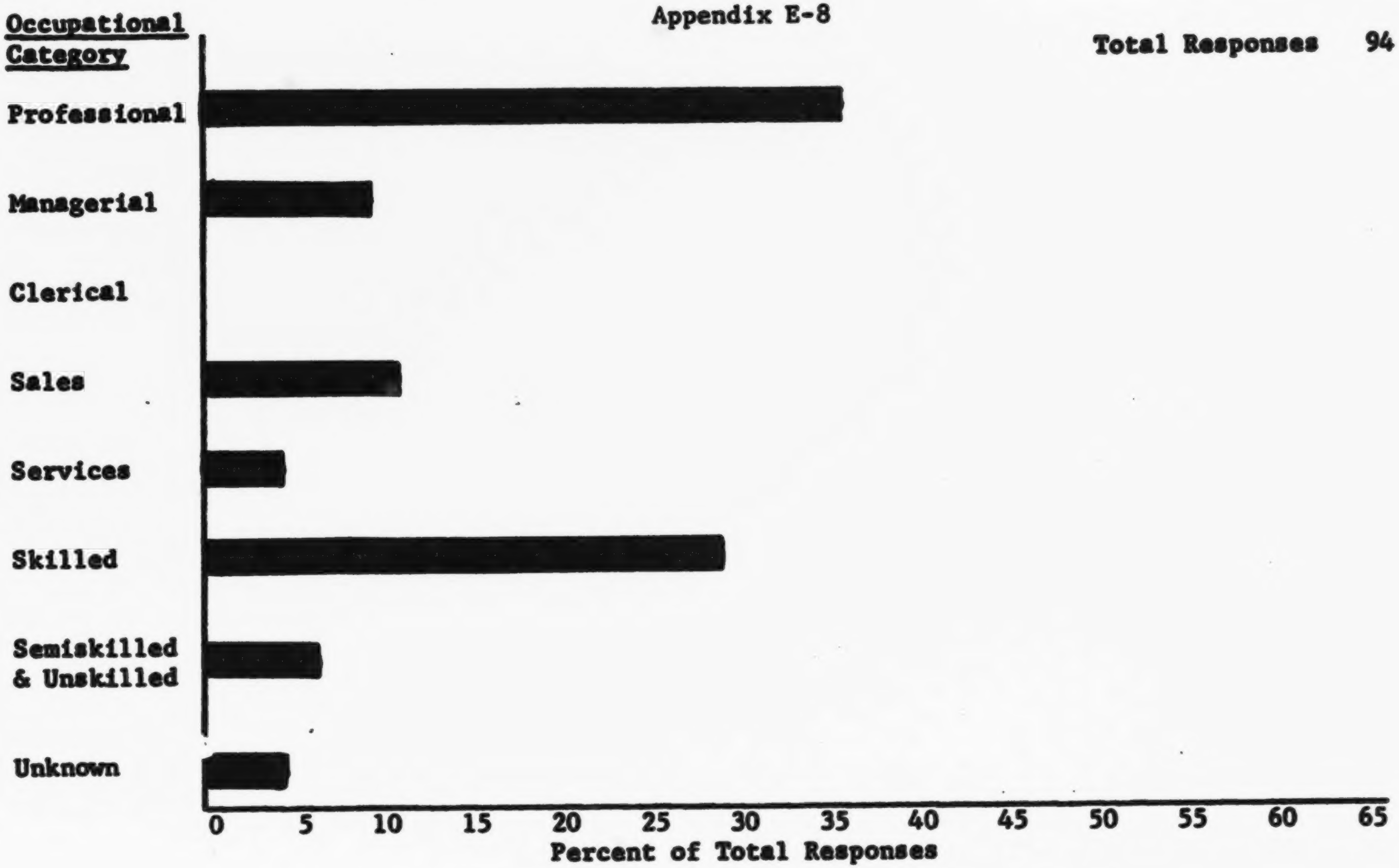


Figure 17 DISTRIBUTION OF OCCUPATIONS OF CHIEF WAGE EARNER IN SCHOOL #8 ACCORDING TO PUPILS' RESPONSES

# Appendix F-1

## INSTRUCTION GIVEN TO CONSULTANTS TO GUIDE SELECTION OF SIGNIFICANT SCIENCE CONCEPTS

Identifying the significant ideas in physical science is largely a matter of judgement and open to dispute. In such an undertaking, one must consider the present state of the physical sciences and try to anticipate which ideas will be particularly fruitful now and in decades ahead. This is indeed an imposing task.

Identifying the significant ideas in physical sciences which will help the elementary school pupil understand and interpret his present and future environment is equally formidable.

In order to achieve some modis operandi, the field of selection has been restricted to three topics: simple machines, electrical energy, heat energy. Next, a set of three conditions was specified in order to define a significant idea. A concept was considered significant if it satisfied all three of the conditions:

1) A concept was considered significant in terms of physical science if it was discussed or explained in one or both of the following texts:

- a) Harvey White; Modern College Physics, D. Van Nostrand Co.; 1956
- b) George Gamow and John Cleveland; Physics: Foundations & Frontiers, Prentice-Hall; 1960.

2) A concept was considered significant for children if it was discussed or explained in one or more of the following textbooks for pupils in grades four through eight:

- a) B. Parker; Machines, Row, Peterson & Co.; 1959
- b) B. Parker; Thermometers, Row, Peterson & Co.; 1959
- c) B. Parker; Electricity, Row, Peterson & Co.; 1959
- d) C. Trexler, et. al.; ABC Science Series, books 5 and 6, American Book Co.; 1961
- e) W. Beauchamp, et. al.; Discovering Our World, book 2, Scott, Foresman & Co.; 1957
- f) S. Blanc, et. al.; Modern Science, books 2 and 3, Holt Rinehart, & Winston; 1963.

3) At least two authorities in physical science and/or science education concur in the judgement that the concept is significant. The consulting authorities were:

- a) Dr. Vaden Miles, Professor of Physics, Wayne State University.

b) Mr. Mario Motter, Elementary Science Supervisor, Exact Science Dept., Detroit Public Schools

c) Dr. Norval Scott, Science Teacher, Detroit Public Schools.

The enclosed listing is the result of this screening process. It is believed that these ideas satisfy conditions one and two. You are being asked to answer the following two questions.

a) In your judgement, are these valid statements?

b) In your judgement, do these statements represent significant aspects of the topic?

Please feel free to recommend removal or re-statement of any idea included in the listing. For your information, a source and page number is included for each concept. This indicates specifically where the idea stated or was implicit in the authors' remarks.

### F-3

## GENERALIZTIONS ABOUT SIMPLE MACHINES USED IN UNIT WITH THEIR DOCUMENTATION IN COLLEGE PHYSICS TEXTS AND K-12 SCIENCE TEXTBOOK SERIES*

### A. MECHANICAL ENERGY AND WORK

1. Energy is the ability to do work. (HRW, W128, G62)

2. Mechanical energy is energy produced by a machine. (HRW, W149)

3. The energy used to do work is not lost or destroyed but its form may be changed. (HRW, W134, G62)

4. A force is a push or pull in some direction. (HRW, W134, G62)

5. A measure of work is the product of a force and the distance through which it moves. (HRW, W124, G61)

6. Work is done when a force moves an object. (HRW, W124, G61)

### B. SIMPLE MACHINES--LEVERS

1. A machine makes it easier to do work. SF, W149)

2. A lever is one kind of simple machine. (RP, W149)

3. Many machines are made by using two or more simple mac hines together. (RP, W149)

4. In a first class lever, the fulcrum is between the load and the effort force. (WRW, W142)

5. In a second class lever, the load is between the effort force and the fulcrum. (HRW, W142)

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Legend: Letters and numerals in parentheses refer to following texts: W128-page 128 in White (93); G181-page 181 in Gamow (25); SI-Singer (23); ABC-American Book Co. (36); RP-Row-Peterson (55); HTW-Holt,Rinehart, Winston (7); SF-Scott Foresman (4)

*Statements are not necessarily in order that they were presented in unit.

6. In a third class lever, the effort force is between the fulcrum and the load. (HRW, W142)

7. The load arm is the distance between the fulcrum and the load. (RQ, W143)

8. The force arm is the distance between the fulcrum and the effort force. (RQ, W143)

9. Pliers, bottle openers, brooms, baseball bats, and shovels are examples of the lever. (RP, W143)

10. When the force arm is longer than the load arm, a small force moves a heavy load. (RP, W143)

11. When the force arm is longer than the load arm, the effort force is moved a greater distance than the load. (RP, W143)

12. When the force arm is as long as the load arm, no mechanical advantage is gained. (RP, W149)

13. When the load arm is longer than the force arm, the load travels farther than the effort force. (RP, W150)

14. When the load arm is longer than the force arm, the load travels faster than the effort force. (RP, W176, G80)

15. When the load arm is longer than the force arm, the effort must be greater than the load in order to move it. (RP, W150)

16. The pulley and the wheel and axle are special kinds of levers. (HRW, W152)

## C. SIMPLE MACHINES--PULLEYS

1. A single fixed pulley needs a force larger than the load to be lifted. (RP, W153)

2. A single fixed pulley is used to move a load by pulling in the opposite direction. (RP, W153)

3. A movable pulley and a small force can be used to lift a heavier load. (SF, W153)

4. Elevators, hoists, steam shovels, and the painters' scaffolds use pulleys. (RF, W154)

5. A load is raised a short distance by a movable pulley, but the lifting force must travel a long distance. (RP, W153)

6. Pulleys can be combined to lift very heavy loads. (RP, W153)

7. The number of strands in a pulley system indicates the gain in lifting force. (RP, W154)

## D. SIMPLE MACHINES--WHEEL AND AXLE

1. When a wheel and axle is turned, a point on the rim of the wheel travels farther than does a point on the rim of the axle. (RP, W152, G78)

2. When a wheel and axle is turned, the edge of the wheel travels faster than the edge of the axle. (RP, W176, G78)

3. A small force on the wheel will move a heavy load on the axle. (SF, W152)

4. As the wheel becomes larger, it takes less force on the wheel to move the same load on the axle. (RP, W143)

5. The wheel and axle is often used in automobiles, bicycles, and home appliances. (HRW)

## E. SIMPLE MACHINES--INCLINED PLANE

1. An inclined plane is another kind of simple machine. (HRW, W129)

2. An inclined plane raises a heavy load a short distance by moving a small force through a long distance. (RP, W129)

3. Wedges and screws are special forms of the inclined plane. (RP)

## F. FRICTION

1. Friction is a force resisting motion between two surfaces in contact. (HRW, W86, G16)

2. Friction produces heat. (RP, W151)

3. There is some friction in every machine when it is being used. (RP, W150, G70)

4. Friction may be classified as: a)sliding friction, b) fluid friction, or c) rolling friction. (HRW, W87)

5. Sliding friction is important in writing, walking, running. (HRW, W87)

6. Fluid friction is important to objects traveling through air, water, or other fluids. (HRW, W91)

7. Rolling friction is important to the use of automobiles, roller skates, bicycles. (HRW, W89)

## F-7

## GENERALIZATIONS ABOUT ELECTRICITY USED IN UNIT OF INSTRUCTION WITH THEIR DOCUMENTATION IN COLLEGE PHYSICS TEXTS AND K-12 SCIENCE TEXTBOOK SERIES*

### A. ELECTRICAL ENERGY

1. Energy is the capacity to do work. (HR, W128, G62)

2. Electrical energy is produced by the flow of charged bodies. (HR, W525, G195)

3. The energy from light, heat, mechanical forces, or chemical action may be changed to electrical energy. (HR, W134, G62)

4. Electrical energy may change to light, heat, mechanical or chemical energy. (HR, W134, G62)

### B. STATIC ELECTRICITY--ATOMIC STRUCTURE

1. All matter is made of atoms. (Singer, W478, G180)

2. Every atom has a nucleus. (Singer, W478, G180)

3. Around each nucleus of an atom are electrons. (Singer, W478, G180)

4. The nucleus of an atom has a positive electrical charge. (Singer, W478, G180)

5. The electrons around the nucleus have a negative charge. (Singer, W478, G180)

6. A neutral substance becomes positively charged when it gives up electrons. (AB, G181)

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Legend: Letters and numerals in parentheses refer to following texts: W128-page 128 in White (93); G181-page 181 in Gamow (25); SI-Singer (23); ABC-American Book Co. (36); RP-Row-Peterson (56); HTW-Holt, Rinehart, Winston (7); SF-Scott Foresman (4).

*Statements are not necessarily in order that they were presented in unit.

7. A neutral substance becomes negatively charged when it takes on additional electrons. (AB, G181)

8. Neutral objects are neither positively nor negatively charged. (AB, W478)

9. Like electrical charges repel each other, but unlike electrical charges attract.

C. STATIC ELECTRICITY--ELECTRICAL CHARGES

1. Some materials readily give up electrons, while other materials readily capture electrons. (RP, W477, G180)

2. Electricity produced by rubbing one material with another material is called static or frictional electricity. (Singer, W475, G178)

3. Electrical charges collect on the surface of a material. (HR, W485, G182)

4. A neutral object is charged by conduction when it comes into contact with a charged object and receives electrons. (HR, G181)

5. Neutral objects can be attracted by either positively or negatively charged objects. (HR, G182)

D. CURRENT ELECTRICITY--OPEN AND CLOSED CIRCUITS

1. When electrons move along a conductor, an electric current is produced. (HR, W486, G195)

2. Current electricity is used more than static electricity. (RP, G228)

3. An electric circuit contains a source of electrical energy and a path through which the current may flow. (RP, G199)

4. A closed circuit has no gaps in the path of the current of electricity. (RP, G199)

5. An open circuit has a gap somewhere in the path of the current. (RP, G199)

6. An electric circuit may be connected in series or in parallel. (RP, W488, G200)

## E. CURENT ELECTRICITY--CONDUCTORS AND NON-CONDUCTORS

1. All materials offer some resistance to an electric current. (RP, W490, G182)

2. An electric current flows easily along good conductors of electricity. (RP,W481, G182)

3. Most metals are good conductors. (RP, W480, G182)

4. An electric current does not flow easily along poor conductors of electricity. (RP, W481, G182)

5. When an electric current flows along a wire, the wire is heated. (SF, W524, G204)

6. In electrical heating appliances a current is sent along a wire which is a poor conductor. (HR, W525, G204)

7. When a large electric current flows along a wire which is a poor conductor, it may become hot enough to give off light. (HR, W524, G204)

## F. CURRENT ELECTRICITY--DIRECT CURRENT AND ALTERNATING CURRENT

1. The chemical changes in an electric cell provide an excess of electrons at the negative terminal and few electrons at the positive terminal. (HR, W486, G196)

2. The increase of electrons at a terminal forms a force which moves electrons along a conductor. (HR, W489)

3. Electrons from the negative terminal of a cell will readily flow along a conductor tending to equalize the number of electrons at each terminal. (HR, W489, G195)

4. Since current produced by a cell flows in one direction only, it is called direct current. (HR, W547, G195)

5. Alternating currents flow first in one direction and then in the opposite direction. (RP, W547)

6. Electricity from a generator may be either direct current (DC) or alternating current (AC). (RP, W524)

7. Electric current may be used to: heat or cook, make light, send messages, and run machines. (RP, W524)

## G. ELECTROMAGNETS

1. Moving a solid conductor through a magnetic field will generate an electric current. (HR3, W543, G220)

2. A magnetic field around a wire is created by sending a current of electricity along the wire. (AB, W528, G211)

3. An electromagnet consists of a piece of iron within a coil of wire, along which a current of electricity is sent. (RP, W529, G214)

4. An electromagnet has a North-seeking pole and a South-seeking pole, just as other magnets do. (SF, W529)

5. An electromagnet can be made stronger by increasing the number of turns of wire wound around the core or by increasing the current. (SF, W537, G212)

6. An electromagnet has considerable force only so long as the electric current is flowing. (SF, W537, G212)

7. Electromagnets are important parts of electric motors. (RP, W531, G218)

## F-11

## GENERALIZATIONS ABOUT HEAT ENERGY USED IN UNIT WITH THEIR DOCUMENTATION IN COLLEGE PHYSICS TEXTS AND K-12 SCIENCE TEXTBOOK SERIES*

### A. MATTER AND HEAT ENERGY

1. Matter exists in three states: solids, liquids, gases. (ABC, W193, G30)

2. Matter is made up of atoms which combine to form molecules. (ABC, W195, G180)

3. The molecules are vibrating and moving very fast. (ABC, W193, G331)

4. In a solid, the molecules are held close together by mutual attraction. (HRW, W199, G328)

5. In a liquid, the molecules are able to flow past one another. (HRW, W197, G328)

6. In a gas, the molecules are relatively far apart. (HRW, W196, G328)

7. Heat energy is the energy of motion of the molecules of a body. (HRW, W271, G153)

8. The sun transfers a great deal of heat energy to earth. (RP, W292, G520)

9. Chemical changes, electricity, and friction are common sources of heat. (RP)

10. Heat energy may be changed to other forms of energy such as light, chemical, electrical, and mechanical energy. (ABC, W134, G176)

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Legend: Letters and numerals in parentheses refer to following texts: W128-page 128 in White (93); G181-page 181 in Gamow (25); SI-Singer (23); ABC-American Book Co. (36); RP-Row Peterson (57); HTW-Holt, Rinehart, Winston (7); SF-Scott Foresman (4).

*Statements are not necessarily in order that they were presented in unit.

## B. MEASURING HEAT ENERGY--TEMPERATURE, THERMOMETERS

1. The amount of heat energy in a material can be measured. (RP, W271, G153)

2. Touching, seeing or other senses are not accurate ways to measure temperature. (RP, W2, G144)

3. Temperature is a measure of the average energy of motion of the molecules in a material. (ABC, W260, G153)

4. Temperature is not a measure of the total amount of heat in a material. (ABC, W271, G153)

5. Thermometers are used to measure temperature. (RP, W260, G144)

6. Thermometers can be made by using air and water, alcohol, or metals. (RP, W260, G145)

7. The fluid in a thermometer indicates temperature changes by expanding when heated and contracting when cooled. (RP, W260, G145)

8. The Fahrenheit scale and Centigrade scale are two common ways of marking thermometers. (RP, W261, G146)

## C. EXPANSION AND CONTRACTION

1. Most matter expands when it is heated and contracts when it is cooled. (ABC, W263, G144)

2. Removing heat from water causes it to contract until 4°C and then water expands until 0°C.

3. Adding heat increases the speed of the molecules in a substance. (ABC, W196, G330)

4. A solid may be changed to a liquid or a gas by adding heat energy. (HRW, W196)

5. Removing heat from a substance will decrease the speed of the molecules. (HRW, W197, G330)

6. Removing heat from a material will cool it. (RP, W288)

7. A gas may be changed to a liquid or solid by removing heat energy. (HRW, W197-200)

8. Evaporation is an important way to cool something. (RP, W297)

D. TRANSFER OF HEAT ENERGY

1. It is natural for heat to travel from a hot region to a cooler region. (HRW, G176)

2. Although heat energy may change its form, it is never lost in moving from one place or form to another. (HRW, W134, G168)

E. TRANSFER OF HEAT ENERGY--CONDUCTION

1. Heat may be transferred by conduction, convection, or radiation. (ABC, W283)

2. In conduction, heat energy is transferred from one molecule to another. (ABC, W284)

3. Heat travels easily through good conductors of heat. (RP, W285, G157)

4. Metals conduct heat better than liquids or gases. (ABC, G157)

5. There are some materials through which heat does not travel easily and they are called poor conductors of heat or insulators. (RP, W283, G157)

6. Paper, water, air and glass are often used as insulators. (ABC, W284, G159)

7. Poor conductors can be used to keep hot things hot or cold things cold. (RP, W188, G159)

8. An insulator keeps most of the heat from moving into a cooler region. (ABC, G176)

F. TRANSFER OF HEAT ENERGY--CONVECTION

1. Convection is the transfer of heat energy of molecules in moving currents of fluids. (ABC, W283, G159)

2. Convection currents in fluids are created when the lighter parts of a fluid are forced upward by cooler and heavier parts which gravity forces downward. (HRW, W285, G159)

3. Convection currents in air occur when warm air is pushed upward by colder, heavier air, which is pulled downward by gravity. (SF, W286, G159)

4. Heat is transferred by molecules in the convection currents to other molecules in the fluid. (ABC, G159)

5. Atmospheric circulation and ordinary ventilation depend upon convection currents. (ABC, W286, G159)

## G. TRANSFER OF HEAT ENERGY--RADIATION

1. Radiation is emitted by almost all materials. (W290, G279)

2. Although most radiant energy cannot be seen, it travels like rays of light. (HRW, W287, G161)

3. Energy from the sun travels to earth by radiation. (ABC, W291, G160)

4. When an object absorbs radiant energy, its molecules move faster and increase its heat energy. (ABC, W289)

5. Mirrors and shinning surfaces reflect radiant energy. (HRW, W291)

6. Dark objects absorb radiant energy. (ABC, W290)

## Appendix G-1

## The Universe of Discourse for the Project and Scoring Multiple-Choice Test Questions

### 1. Members of the Universe of Discourse

For the purposes of this study, the expression "universe of discourse" referred to all of the written and spoken symbols and the imagery used to communicate a set of ideas about simple machines, electrical energy, and heat energy to all pupils in the sample. This included the symbols and ideograms used in the texts, filmstrips, class discussions, experiments or activities, and similar events which were intended to communicate ideas or percepts of the topic being studied. The written plans of instruction in Appendix I attempted to communicate certain stereotypes and conventional relationships among them. In discussing the plans of instruction with teachers, the researcher always specified that any of the ideas being studied were subject to change and refinement as the pupil learned more about the world in which we live.

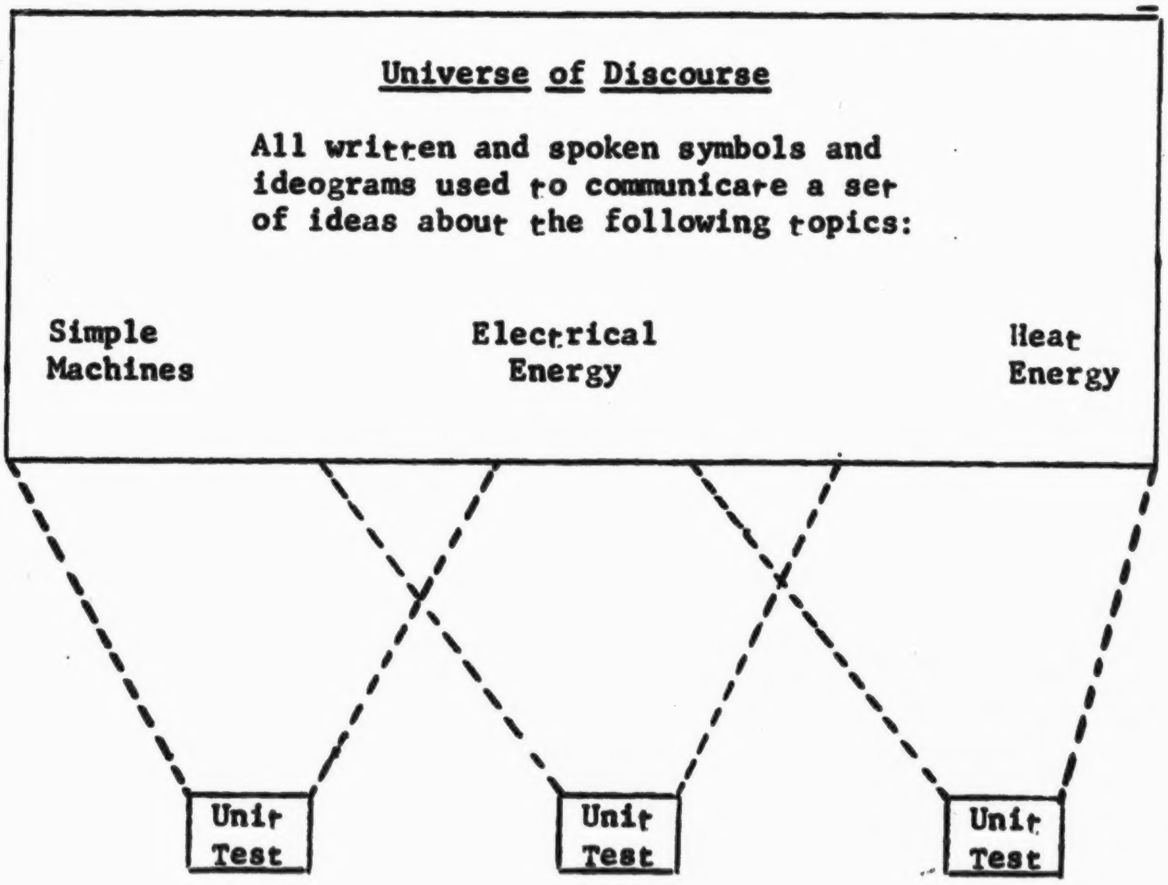
The instructional program conducted in this study may be considered an information processing task for the pupils. Their understandings of these components may be evaluated in terms of the pupils' successes or failures in identifying and retaining their perceptions of the conventions or stereotypes in the universe of discourse.

The multiple-choice test items were composed of the verbal symbols and ideograms which formed a subset of the universe of discourse. Pupils' responses (correct or incorrect) to test items provided an indication of their understanding or misunderstanding of these components and the conventioal relationships among them. Each collection of 50 test questions provided an estimate of the pupils' success in coping with this information processing problem.

This is illustrated in Figure 18, in which the rectangle at the top of the figure refers to all of the concepts taught, understood, and misunderstood during the entire unit of instruction. That is, the rectangle refers to all of the elements in the universe of discourse. If one considers the large number of pupils, teachers, instructional materials and time devoted to each unit, it should be obvious that the universe of discourse includes a tremendously large number of elements. The small rectangles at the bottom of the figure indicate the 50 item tests which were used to provide an estimate of the pupils' understanding of the much larger set of generalizations in the universe of discourse. To be very precise, each of the tests should also be considered as members of the universe of discourse.

G-2

Figure 18 RELATIONSHIPS OF THE UNIVERSE OF DISCOURSE TO THE UNIT ACHIEVEMENT TESTS


Universe of Discourse
All written and spoken symbols and
ideograms used to communicate a set
of ideas about the following topics:
Simple Machines
Electrical Energy
Heat Energy
Unit Test
Unit Test
Unit Test

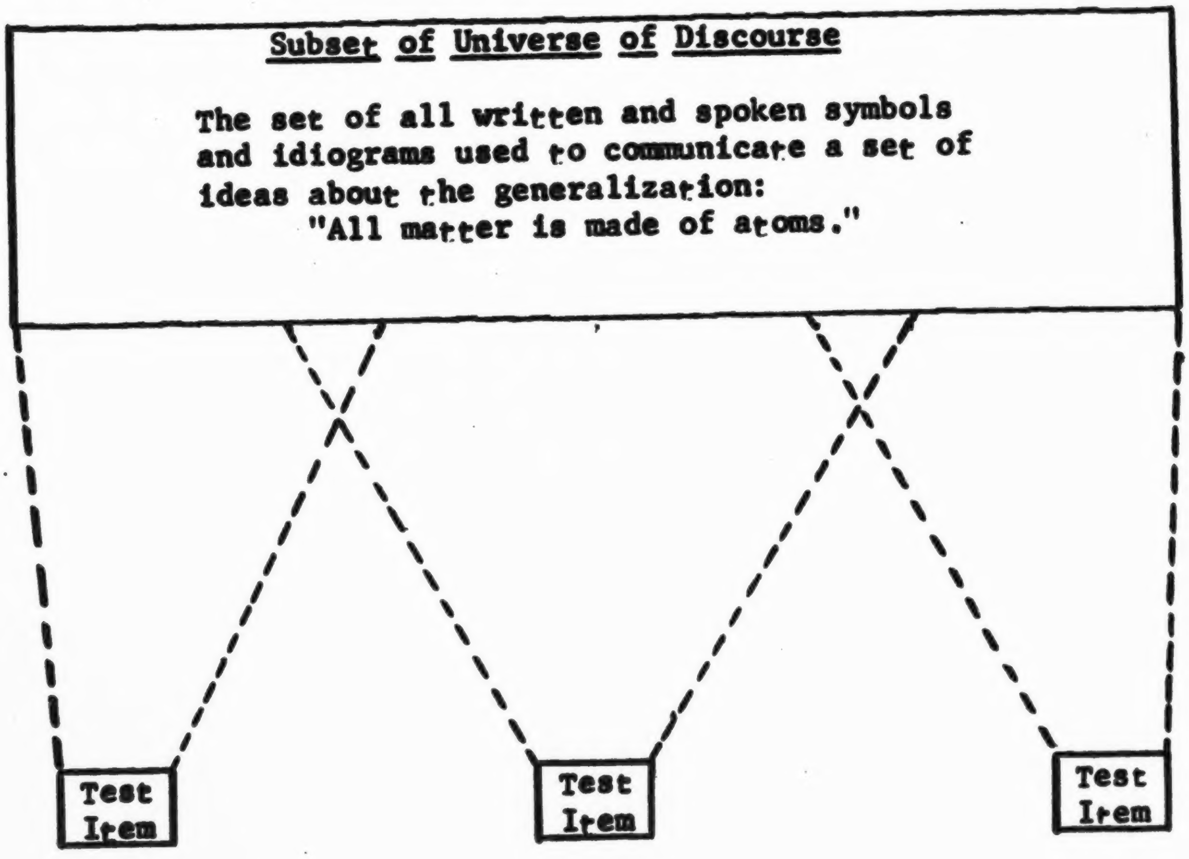
It should be noted that the test item generalizations are also crude assessments of pupils' understanding of the broad science generalization to which the test item corresponds. Each individual test item forms a minimal level of measurement of pupils' understanding of the corresponding science generalization. Moreover, the major science generalization is simply one of the generalizations which constituted the universe of discourse.

This has been illustrated in Figure 19 , which used a rectangle at the top of the figure to refer to a sub-set of the universe of discourse. This sub-set includes all written and spoken symbols and ideograms used to communicate a set of ideas about the single generalization: "All matter is composed of atoms." The major science generalization was merely one of the generalizations in the universe of discourse, but it also contained a very large number of elements.

In contrast to the large number of elements in this sub-set, the figure indicates that only three test items were used to estimate pupils' understandings or misunderstandings of this major science generalization. This is also illustrated by the three "test item" rectangles at the bottom of Figure 19 . These test items are considered members of a much larger collection of test items which might have been utilized to assess pupils' comprehension of the major science generalization.

G-4

Figure 19 RELATIONSHIP OF THREE TEST ITEMS TO A SINGLE GENERALIZATION IN THE UNIVERSE OF DISCOURSE



Subset of Universe of Discourse

The set of all written and spoken symbols and idiograms used to communicate a set of ideas about the generalization:
"All matter is made of atoms."

## 2. Scoring Pupils' Responses to Test Items

If a pupil responds correctly to the pre-test for simple machines (M12), then this provides some indication of the individual's understanding of the idea which corresponds to that test item. If there are four options as correct answers, then a pupil may guess the correct answer approximately 1/4 of the time. However the use of double precision scoring required the pupil to make the same correct response on the pre-test (M12) and on the post-test (M23) administered after instruction has concluded. This double precision scoring is indicated by the expression (M12) for the machines pre-test, and it implied that the probability of guessing the correct response was the product of the fraction (1/4) • (1/4) or 1/16.

It has been argued, that these are not independent administrations of different test items and therefore there will be a practice effect which would alter the 1/16 estimate of the likelihood of random guessing. The researcher would argue that it is very unlikely that an intermediate grade pupil would remember the exact response that he made to a particular test item during a 30-minute period when it was administered and retain that exact impression for five to eight weeks until the post-test was administered during another 30-minute period. The researcher would argue that a tremendously large number of events occur to any child in an elementary school during a five hour day and that this is further complicated by the events which happen to that child at home and in other activities during the five to eight weeks between test administrations. As a consequence of the researcher's experience, he has come to believe that pupils have many activities and problems to concern them other than waiting for some particular test item or set of test items to be administered to them at some particular time in the distant future.

To be sure, some test items may be so unusual that the child will recall his particular response to the test question, but the researcher is not inclined to believe that there were a large number of these items on any of the unit achievement tests.

Therefore, the researcher has argued that the probability that any youngster will respond correctly to the double precision test item (M12) or any of the other double precision test items is approximately 1/16. If the reader is not persuaded by these arguements, then he would be advised to modify his confidence in the results of this study.

The "double precision" scoring procedure suggests that it is important to have precise information about what was understood by pupils before instruction and what was understood and retained by pupils after instruction had ended. It assumes that a pupil who understands the "conventional" or "stereotype" answer to a question before instruction, will also select that appropriate answer after instruction. It also makes the assumption that if the generalization was not remembered by a pupil, then the pupil will be seriously handicapped in utilizing that generalization to help him to interpret the world in which he lives.

Figure 20 shows a tree diagram of responses which any pupil might make to any test item on the pre-test, post-test, and retention test for each unit of instruction. It is obvious that the pupil may respond in such a way as to have a correct answer, an incorrect answer, or the test instructions permitted him to indicate that the answer was unknown to him. The tree diagram makes it possible to define rather precisely the segments which indicate the pupil's understanding or lack of understanding of the idea being measured by the test question. In the figure, the heavy dark line indicates a hypothetical path of correct answers to this test question administered on the pre-test, post-test, and retention test. The various branches of the tree diagram suggest error patterns which might occur for any of the 50 test items for any pupil in the sample. At the end of Appendix G, there is a listing of misconceptions which may be inferred from the various error responses to questions included in the machines test.

If the reader can conceive of a network of 50 more tree diagrams similar to the diagram in Figure 20, then he will have a general idea of the possible response paths open to each pupil in this study, for a single unit achievement test. Conventional scoring precedures recommend tallying the correct points in that maze of interlocking lines to indicate the success or failure of a pupil in some endeavor. Sometimes, the conventional scoring procedures favor "correction for guessing" by subtracting a fractional portion of the incorrect responses from the correct response tally. The extent to which this oversimplifies the problem should be apparent to the reader.

Double precision scoring makes a modest improvement, in the judgement of the writer, by suggesting that the segment between the consistently correct or the consistently incorrect responses should be utilized as indicators of pupils' success or failure. In this project, the researcher has written a computer program which conducted the double precision scoring tasks and provided an English printout of the correct as well as the incorrect responses. A sample of an individual profile is also included in Appendix G.

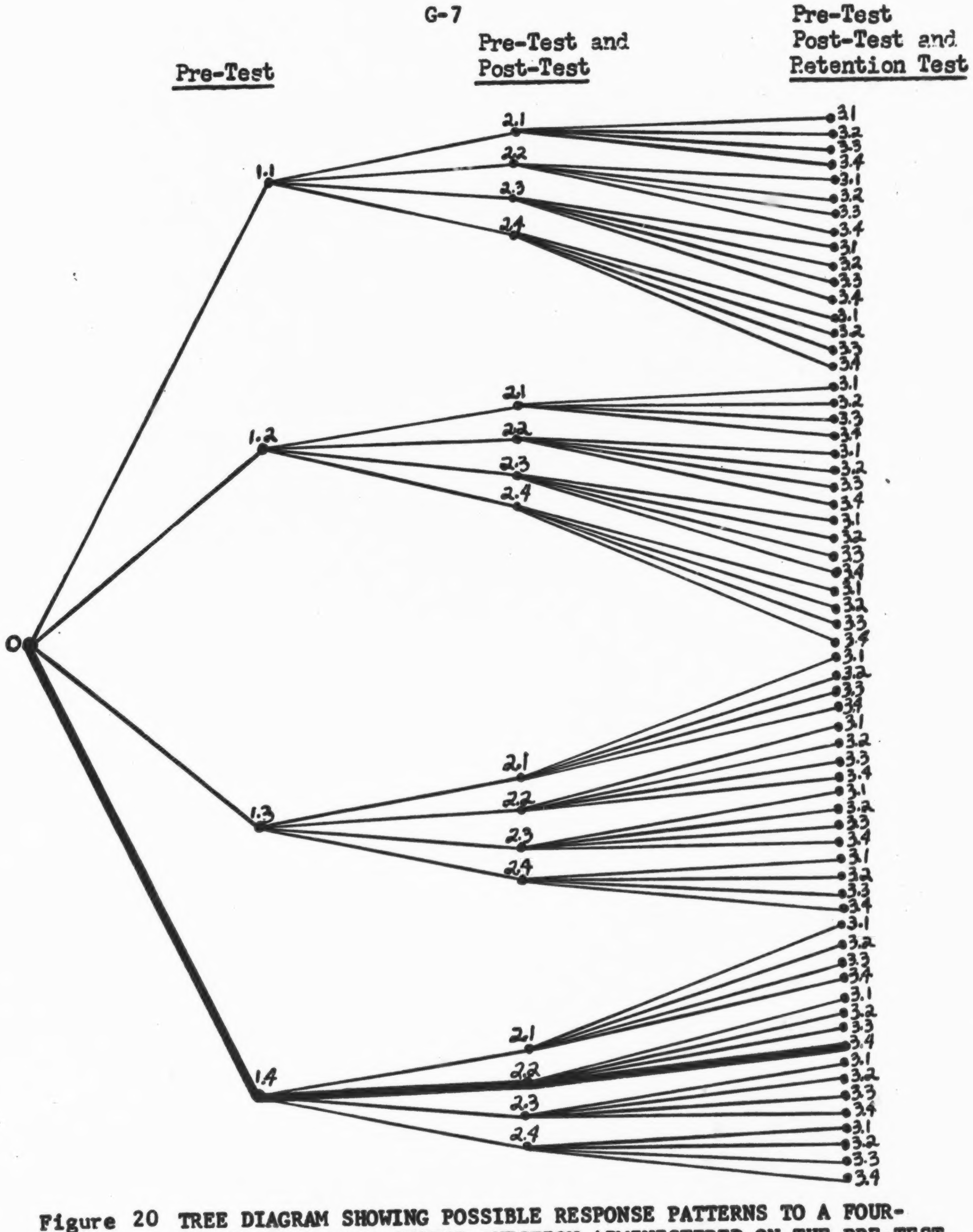

Pre-Test
Pre-Test and Post-Test
Pre-Test Post-Test and Retention Test
0
1.1
1.2
1.3
1.4
2.1
2.2
2.3
2.4
3.1
3.2
3.3
3.4

Figure 20 TREE DIAGRAM SHOWING POSSIBLE RESPONSE PATTERNS TO A FOUR-OPTION, MULTIPLE-CHOICE QUESTION ADMINISTERED ON THE PRE-TEST, POST-TEST, AND RETENTION TEST.

It is the writer's view that the raw score or total of correct responses to any multiple-choice test is a very crude indicator of a pupil's understanding or misunderstanding of any topic. There is a tremendous amount of information about the pupil's understanding or misunderstanding, which is recorded on his answer sheet. With the availability of high speed data processing equipment, researchers have an obligation and an exciting challenge to pursue the other branches in the network of pupils' responses to the multiple-choice questions.

G-9

```
COMPUTER PRINT- DIAGNOSTIC PROFILE OF PUPIL-S UNDERSTANDING
                   OF SCIENCE TOPICS (10/1/66)

 ID  NAME                        SCHOOL,TEACHER       GRD SSS IQQ RDG SEC

1349 GREEN,THOMAS                CERVENY,JACKSON        5  52 109  53 MID

TOPIC REQUESTED   ELECTRICITY        -   INFORMATION IS AVAILABLE
 A. TOPICS AND CONCEPTS UNDERSTOOD*

  1.ELECTRICAL ENERGY
    E2  ENERGY OF LIGHT,HEAT,CHEM CHG MAY BE CHANGED TO ELE ENERGY
  2.STATIC ELECTRICITY-ATOMIC STRUCTURE
    E3 ALL MATTER IS MADE OF ATOMS
    E4 EVERY ATOM HAS NUCLEUS
    E5 AROUND NUCLEUS OF ATOM ARE ELECTRONS
    E7 ELECTRONS HAVE (-) CHARGE
 * UNDERSTANDING BASED ON CORRECT RESPONSES TO POST-UNIT TEST AND
   RETENTION TEST QUESTIONS AFTER INSTRUCTION DURING 1965-1966

 B.TOPICS AND CONCEPTS MISUNDERSTOOD**

  2.STATIC ELECTRICITY - ATOMIC STRUCTURE
    E6  NUCLEUS OF ATOM HAS (+) CHARGE
    E8  NEUTRAL MATL BECOMES (+) WHEN IT GIVES UP ELECTRONS
    E9  NEUTRAL MATL BECOMES (-) WHEN IT GAINS ELECTRONS
  3.STATIC ELECTRICITY - ELECTRICAL CHARGES
    E14 ELEC CHARGES COLLECT ON SURFACE OF MATERIAL
**MISUNDERSTANDING BASED UPON INCORRECT RESPONSES TO POST-UNIT TEST AND
  RETENTION TEST QUESTIONS AFTER INSTRUCTION DURING 1965-1966

 C. INQUIRY SKILLS IN SCIENCE
  1.DEFINING PROBLEMS - NO INFORMATION
  2.GENERATING HYPOTHESES -NO INFORMATION
  3.SKILL IN FORMING GENERALIZATIONS - NO INFORMATION
  4.SKILL IN FORMING WAYS TO TEST IDEAS - NO INFORMATION

  5.PROFICIENCY IN LOGICAL REASONING - NO INFORMATION
 D. PREVIOUS STUDIES OF TOPIC - NO INFORMATION
 E. PREVIOUS STUDIES OF PHYSICAL SCIENCE TOPICS,DATES,MATLS- NO INFORM
```

## G-10

## COMPUTER PRINTOUT - DIAGNOSTIC PROFILE OF CLASS-5 UNDERSTANDING OF SCIENCE TOPICS (10/1/66)

```
A. IDENTIFICATION-
    CLASS -  NO PUPL  -   SCHOOL-TCHR  -    GRADE
   SECTION II (35)     CERVENY (JACKSON)      5

B. PREVIOUS TEST RESULTS -   1961-2  1962-3  1963-4  1964-5  1965-6
    1.MEDIAN SCIENCE
    2.MEDIAN IQ
    3.MEDIAN READING COMP

C. SOCIO-ECON TRAITS OF SCHOOL COMMUNITY
    .05 PROF, .07 MGRL, .43 SKLD, .20 SALES, .25 SERVICE,

D. TOPICS AND CONCEPTS UNDERSTOOD*                                PERCENT
  1.ELECTRICAL ENERGY -                            CLASS  MEDIAN  .45
    E1 ELEC ENERGY PRODUCED BY FLOW OF CHARGED BODIES                .40
    E2 ENERGY OF LIGHT,HEAT,CHEM CHG MAY BE CHANGED TO ELEC ENER     .50

  2.STATIC ELECTRICITY - ATOMIC STRUCTURE          CLASS  MEDIAN  .50
    E3 ALL MATTER IS MADE OF ATOMS                                   .80
    E4 EVERY ATOM HAS NUCLEUS                                        .82
    E5 ELECTRONS TRAVEL AROUND NUCLEUS OF ATOM                       .75
    E6 NUCLEUS OF ATOM HAS (+) CHARGE                                .40
    E7 ELECTRONS HAVE (-) CHARGE                                     .70
    E8 NEUTRAL MATL BECOMES (+) CHARGED WHEN IT LOSES ELECTRONS      .10
    E9 NEUTRAL MATL BECOMES (-) CHARGED WHEN IT SAINS ELECTRONS      .15
    E10 NEUTRAL MATL IS NEITHER (+) NOR (-) CHARGED                  .50
    E11 LIKE ELECTRICAL CHARGES REPEL, UNLIKE CHARGES ATTRACT        .20
```

## Student Misunderstanding as Indicated by Incorrect Responses to Items on Machines Test

11. Student believes that earth has mechanical energy for use.

13. Student believes that sun has mechanical energy ready for use.

14. Student believes that wood has mechanical energy ready for use.

21. Student believes a boy retains energy after using energy in race.

22. Student believes a boy has "used up" all energy in running race.

23. Student believes a boy did not use energy in running a race.

31. Student believes no work is done when water is running into a sink.

32. Student believes no work is done when a boy throws a ball.

34. Student believes no work is done when water is running, a boy throws a ball, or man leans against tree.

42. Student believes no work is done when a pencil is used to scribble on paper.

43. Student believes no work is done when a pencil is thrown at wall.

44. Student believes no work is done when a pencil rests on a desk, is used to scribble on paper, or is thrown at a wall.

51. Student believes that in a second-class lever, the fulcrum is between load and force.

53. Student believes that for a second-class lever, the load is placed on top of the force.

54. Student believes that for a second-class lever, the force is between fulcrum and load.

61. Student believes that for a third-class lever, the fulcrum is between the load and force.

62. Student believes that for a third-class lever, the load is between the fulcrum and force.

63. Student believes that for a third-class lever, the load is on top of the force.

71. Student believes that a load can be moved by an equivalent force when force arm equals the load arm.

72. Student believes that a load can be moved by an equivalent force when the load arm is greater than force arm.

74. Student believes that the load will be lifted when a greater force between the load and fulcrum pushes the load downward.

82. Student believes that no work is done when load equals force, and the load arm is greater than the force arm.

83. Student believes that no work is done when a ten pound load on a long load arm is acted upon by 100 pound load on short force arm.

84. Student believes that no work is done when a ten pound load and a 100 pound force are exerted in the same direction.

91. Student believes that load and force travel the same distance when load arm is greater than force arm.

92. Student believes that the load and force travel at the same speed when the load arm is greater than force arm.

94. Student believes that a 100 pound force on a small force arm will travel farther than a ten pound load on a long load arm.

102. Student cannot identify load arm and force arm in a first-class lever.

103. Student cannot distinguish between load arm and force arm in first-class lever.

104. Student cannot distinguish between load arm and force arm in first-class lever.

111. Student cannot distinguish between load arm and force arm in a first-class lever and a third-class lever.

113. Student cannot distinguish between load arm and force arm in two first-class levers.

114. Student cannot distinguish between force arm and load arm

in two first-class levers.

121. Student believes that thirty pound force will not move ten pound load when load arm is twice as large as force arm.

123. Student believes that great force on a long force arm will not move a small load on a small load arm.

124. Student believes that a large force will not move a small load when the force arm equals the load arm.

131. Student believes that a large force on a small force arm travels at the same speed as a small load on a large load arm.

132. Student believes that a large force on a large force arm will travel at the same speed as a small load on a small load arm.

133. Student believes that a large force on a large force arm will travel at same speed as small load on small load arm.

141. Student believes that large force on small force arm will travel farther than small load on large load arm.

142. Student believes that large force on large force arm can be moved by small load on small load arm.

144. Student believes that when the force arm equals the load arm, the large force travels farther than the small load.

152. Student believes that a large force on a large force arm can be moved by a small load on a small load arm, and the small load will travel faster than the larger force.

153. Student believes that a large force on a large force arm and a small load on a small load arm will cause the small load to travel faster than the force.

154. The student believes that when the force arm equals the load arm, the small load travels faster than the larger force.

161. The student believes that when a large force on a small force arm and a small load on a large force arm are used, then the load and force travel the same distance.

162. The student believes that the small load on a small load arm can move a large force on a large force arm, and the load and force will travel the same distance.

163. The student believes that a small load on a small load arm

can be moved by a large force on a large force arm, and the force and load will travel the same distance.

171. The student believes that a shovel is not usually used as a lever.

173. The student believes that a crowbar is not usually used as a lever.

174. The student believes that a hammer is not usually used as a lever.

182. The student believes when the force arm of a lever is made longer, then the load is harder to move.

183. The student believes that when the force arm is made longer for a lever, then this does not change the speed at which the force moves.

184. The student believes that when the force arm is made longer, then the load will move faster.

191. The student believes that when a lever is to be used to lift a rock, the fulcrum should be near the rock or directly under it so that the smallest force will be used to lift it.

192. The student believes that when a rock is to be lifted by a lever the fulcrum should be placed close to the rock or directly under it so the smallest force will be used to lift it.

194. The student believes that when a rock is to be lifted with a lever the fulcrum should be placed far away from the rock so the smallest force will be used to lift it.

201. The student believes that a 60 pound force will balance evenly with a 20 pound load on a single fixed pulley.

202. The student believes that a 60 pound force moves faster than 20 pound load on a single fixed pulley.

203. The student believes that the 20 pound load travels farther that the 60 pound force on a single fixed pulley.

212. The student believes that a 50 pound load can be raised by a ten pound force on a single fixed pulley.

213. The student believes that a ten pound load can be raised by nine pound force on a single fixed pulley.

214. The student believes that a ten pound load can be raised by a five pound force on a single fixed pulley.

221. The student believes that a 50 pound load can be raised by a 25 pound force on a single fixed pulley.

222. The student believes that a 50 pound load can be moved by a 50 pound force used on a single fixed pulley(friction not considered by pupils).

224. The student believes that a 50 pound load can be moved by a force of less than 50 pounds on a single fixed pulley.

231. The student believes that a load on a two-strand movable pulley travels faster than the lifting force.

233. The student believes that a 50 pound load cannot be moved by a 40 pound force on a two-strand movable pulley.

234. The student believes that the load on a two-strand movable pulley will travel farther than the moving force.

241. The student believes that a flag pole does not usually use a pulley.

243. The student believes that a steam shovel does not ordinarily use a pulley.

244. The student believes that an elevator does not usually use a pulley.

251. The student believes that the load on a movable pulley travels farther than the lifting force.

252. The student believes that the load on a movable pulley travels as far as the force which lifts it.

253. The student believes that a load on a movable pulley can be raised two feet by a force which travels only three feet.

262. The student believes that a two-strand movable pulley requires less effort than a four-strand movable pulley to lift a load.

263. The student believes that a two-strand movable pulley uses less effort to lift a load than a four-strand movable pulley.

264. The student believes that a single fixed pulley requires less effort to move a load than a four-strand movable pulley.

271. The student believes that when a large diameter wheel and a small diameter wheel make a complete turn, they will travel the same distance.

272. The student believes that when a small wheel and a large wheel make one complete turn, the small wheel travels faster.

274. The student believes that when a large wheel and a small wheel make one complete turn, the small wheel travels farther than the large wheel.

282. The student believes that when a bicycle wheel is turned, the point at the center travels farther than other points on the wheel.

283. The student believes that when a bicycle wheel is turned, a point on one of the spokes travels farther than a point on the ring.

284. The student believes that when a bicycle wheel is turned, all points on the wheel travel the same distance.

292. The student bleieves that when an airplane propeller is turned, a point at the center travels farther and faster than any other point on the propeller.

293. The student believes that when an airplane propeller is turned, a point in the middle of the blade travels farther and faster than a point on the tip.

294. The student believes that when an airplane propeller is turned, all points on the propeller travel at the same speed.

301. The student believes that when an electric fan blade is turned, a point at the center travels faster than any other point on the blade.

302. The student believes that when an electric fan blade is turned, a point in the middle of the blade travels faster than a point on the tip.

304. The student believes than when an electric fan blade is turned, all points on the blade travel at the same speed.

311. The student believes that a 40 pound load on a small axle will lift a 20 pound load on the large wheel of the wheel and axle machine.

313. The student believes that a wheel and axle machine operates by having both weights go down.

314. The student believes that a 40 pound weight on the small axle of a wheel and axle machine will balance a 20 pound weight on its large wheel.

321. The student believes that a narrow handle of a screw driver will make it easy to turn a screw.

322. The student believes that a slender handle of a screw driver makes it easy to turn a screw.

323. The student believes that a long blade and a long handle make it easy to turn a screw.

331. The student cannot identify a large axle arm of a wheel and axle.

333. The student cannot identify a large axle arm of a wheel and axle.

334. The student cannot identify a large axle arm of a wheel and axle.

341. The student believes that a small wheel of a wheel and axle will use the least force to move a load.

342. The student believes that a small wheel of a wheel and axle will use the least force to move a load.

343. The student believes that a moderate size wheel of a wheel and axle machine uses the least force to move a load.

352. The student believes that traveling up a set of stairs is an example of a screw.

353. The student believes that traveling up a flight of stairs is an example of a lever.

354. The student believes that traveling up a set of stairs is an example of a wedge.

361. The student believes that the screw with the smallest number of threads is easiest to use in wood.

362. The student believes that a screw with a few threads is easier to use in wood than a screw with many threads.

364. The student believes that the screw with the least number of threads is easier to use in wood than a screw with many threads.

371. The student believes that the wedge with a 20 degree angle

is easier to use in wood than a wedge with a 5 degree angle.

372. The student believes that the wedge with a 50 degree angle is easier to use in wood than a wedge with a 5 degree angle.

373. The student believes that the wedge with a 70 degree angle is easier to use in wood than a wedge with a 5 degree angle.

382. The student believes that friction does not exist between a man and air passing over him.

383. The student believes that friction does not exist between the sail on a boat and wind passing over it.

384. The student believes that friction does not exist between a boat and the water it floats upon.

391. The student believes that friction is greater where a person is stnading than at a point supporting a large box and the person.

393. The student believes that friction is greatest on some point on an inclined plane.

394. The student believes that friction is greater where a force is exerted to move a large box supporting a person than at a point under the box.

401. The student believes that friction does not exist between a man and air passing over him.

402. The student believes that friction does not exist between a wagon and air passing over it.

403. The student believes that friction does not exist between the sidewalk and a wagon traveling over it.

411. The student believes that when hands are rubbed together quickly they become warm because energy is passing from one hand to the other hand.

412. The student believes that when hands are rubbed together quickly they become warm because of mechanical energy between the hands.

414. The student believes that when hands are rubbed together quickly, they become warm because the hands are moving.

421. The student believes that a fan has some friction but roller skates or airplanes may not have friction.

422. The student believes that roller skates have some friction but fans or airplanes may not have friction.

423. The student believes that airplanes have some friction but fans or roller skates may not have friction.

431. The student believes that roller skating on a sidewalk is an example of sliding friction.

432. The student believes that singing in the wind is an example of sliding friction.

434. The student believes that swimming in a lake is an example of sliding friction.

441. The student believes that swimming is not an example of fluid friction.

442. The student believes that the Mississippi River is not an example of fluid friction.

443. The student believes that a thunder storm is not an example of fluid friction.

452. The student believes that writing on a chalk board is an example of rolling friction.

453. The student believes that running to an automobile is an example of rolling friction.

454. The student believes that walking on a sidewalk is an example of rolling friction.

461. The student believes that grinding friction is important to objects traveling through air.

463. The student believes that rolling friction is important to objects traveling through air.

464. The student believes that sliding friction is important to objects traveling through air.

471. The student believes that sliding friction is important to the use of automobiles, roller skates, and bicycles.

473. The student believes that grinding friction is important to the use of automobiles, roller skates, and bicycles.

474. The student believes that fluid friction is important to the

9

use of automobiles, roller skates, and bicycles.

481. The student believes that when a 100 pound stick man travels upward for five feet that he has done 104 units of work.

482. The student believes that when a 100 pound stick man travels upward for five feet that he has done 400 units of work.

483. The student believes that when a 100 pound stick man travels upward for five feet that he has done 120 units of work.

491. The student believes that if two pounds of snow are lifted six feet, then eight units of work have been done.

492. The student believes that if two pounds of snow are lifted six feet then four units of work have been done.

494. The student believes that if two pounds of snow are lifted six feet then three units of work have been done.

501. The student believes that if three boys jump off a six foot porch then three units of work were done.

502. The student believes that if three boys jump off a six foot porch then 18 units of work were done.

504. The student believes that if three boys jump off a six foot porch then no work was done.

FIGURE 21

G-21

SIMPLIFIED FLOWCHART ILLUSTRATES MONTE CARLO SIMULATION FOR ESTIMATING TEST RELIABILITY

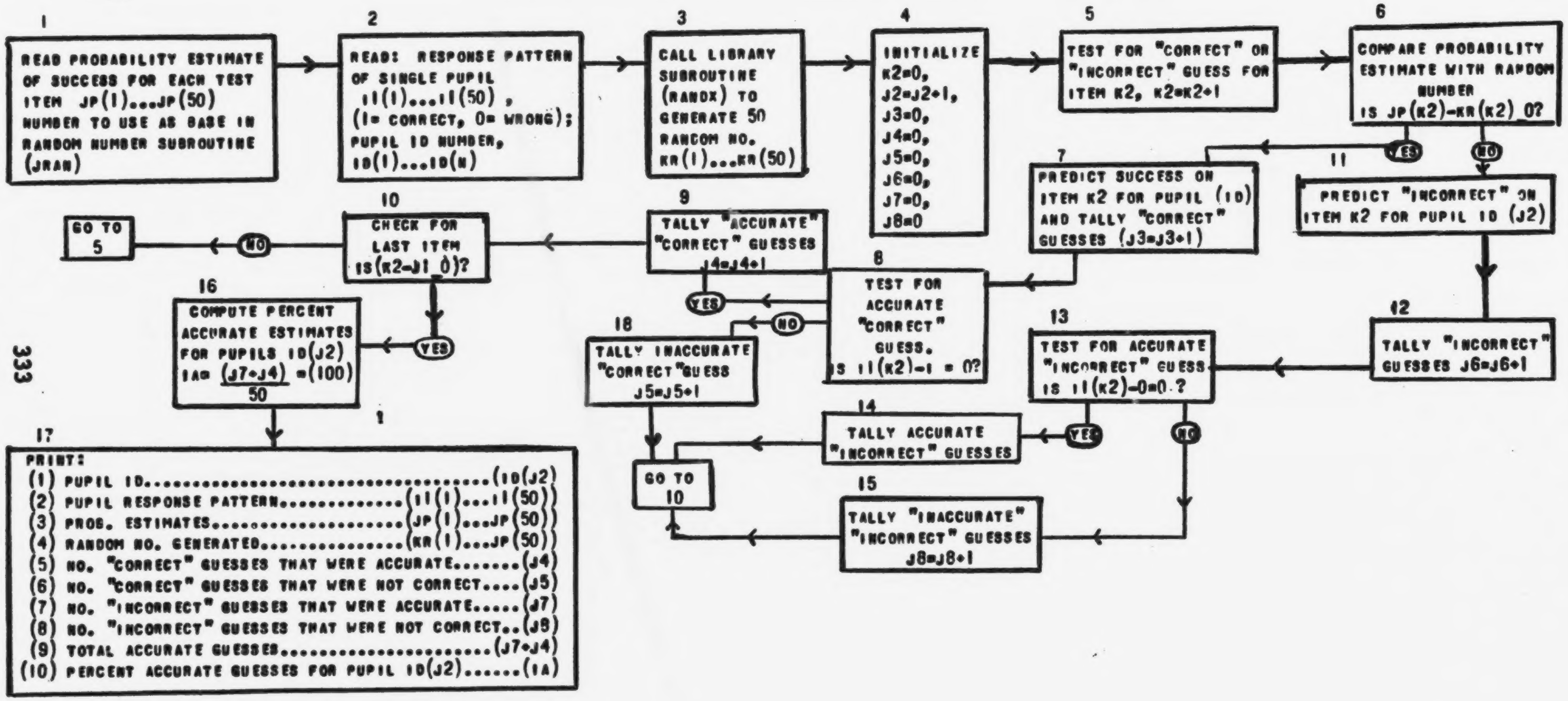
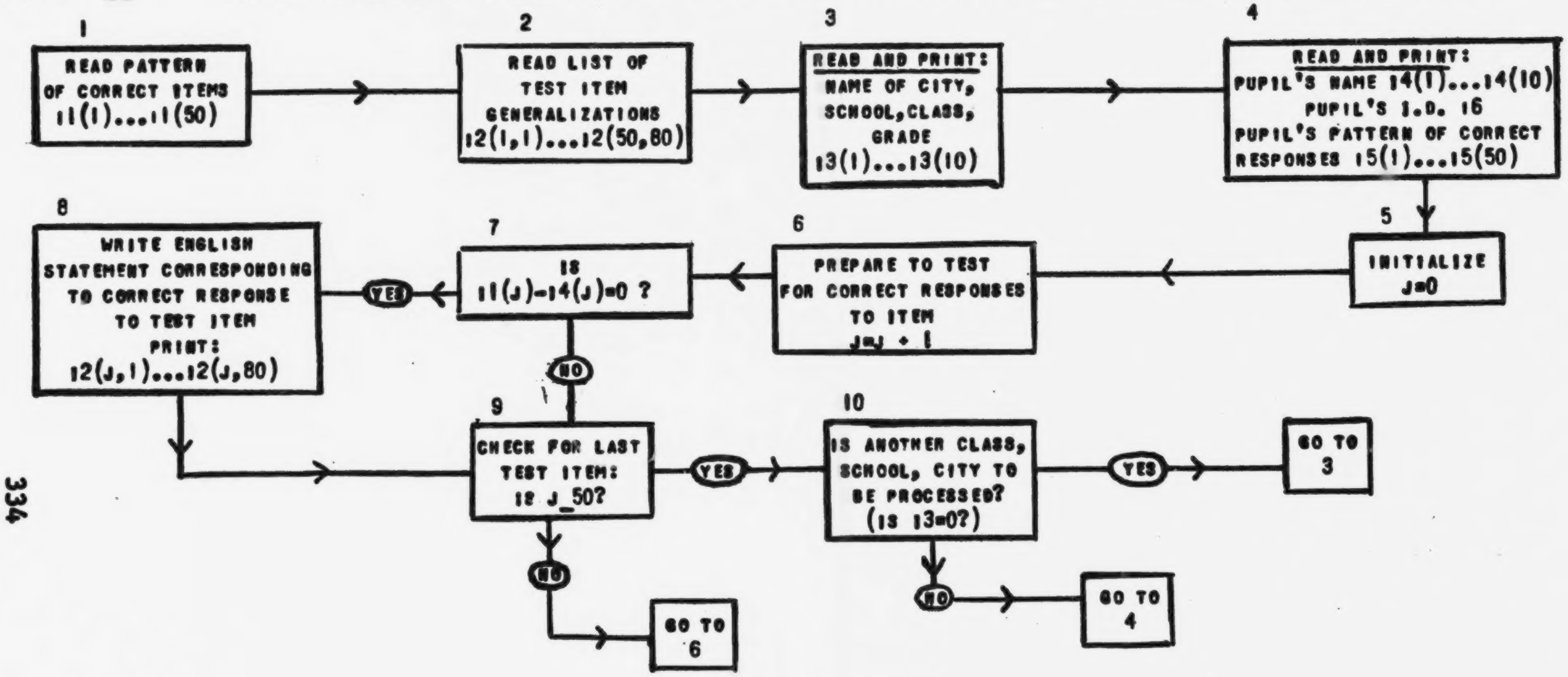

1
READ PROBABILITY ESTIMATE OF SUCCESS FOR EACH TEST ITEM JP(1)...JP(50) NUMBER TO USE AS BASE IN RANDOM NUMBER SUBROUTINE (JRAN)
2
READ: RESPONSE PATTERN OF SINGLE PUPIL II(1)...II(50), (1= CORRECT, 0= WRONG); PUPIL ID NUMBER, ID(1)...ID(N)
3
CALL LIBRARY SUBROUTINE (RANDX) TO GENERATE 50 RANDOM NO. KR(1)...KR(50)
4
INITIALIZE K2=0, J2=J2+1, J3=0, J4=0, J5=0, J6=0, J7=0, J8=0
5
TEST FOR "CORRECT" OR "INCORRECT" GUESS FOR ITEM K2, K2=K2+1
6
COMPARE PROBABILITY ESTIMATE WITH RANDOM NUMBER IS JP(K2)-KR(K2) 0?
YES
NO
7
PREDICT SUCCESS ON ITEM K2 FOR PUPIL (ID) AND TALLY "CORRECT" GUESSES (J3=J3+1)
11
PREDICT "INCORRECT" ON ITEM K2 FOR PUPIL ID (J2)
8
TEST FOR ACCURATE "CORRECT" GUESS. IS II(K2)-I = 0?
YES
NO
9
TALLY "ACCURATE" "CORRECT" GUESSES J4=J4+1
10
CHECK FOR LAST ITEM IS(K2-J1 0)?
NO
GO TO 5
YES
16
COMPUTE PERCENT ACCURATE ESTIMATES FOR PUPILS ID(J2) IA= (J7+J4)/50 =(100)
1
18
TALLY INACCURATE "CORRECT" GUESS J5=J5+1
12
TALLY "INCORRECT" GUESSES J6=J6+1
13
TEST FOR ACCURATE "INCORRECT" GUESS IS II(K2)-0=0.?
YES
NO
14
TALLY ACCURATE "INCORRECT" GUESSES
15
TALLY "INACCURATE" "INCORRECT" GUESSES J8=J8+1
GO TO 10
17
PRINT:
(1) PUPIL ID....................................(ID(J2)
(2) PUPIL RESPONSE PATTERN...............(II(1)...II(50))
(3) PROB. ESTIMATES.........................(JP(1)...JP(50))
(4) RANDOM NO. GENERATED...................(KR(1)...JP(50))
(5) NO. "CORRECT" GUESSES THAT WERE ACCURATE........(J4)
(6) NO. "CORRECT" GUESSES THAT WERE NOT CORRECT.....(J5)
(7) NO. "INCORRECT" GUESSES THAT WERE ACCURATE......(J7)
(8) NO. "INCORRECT" GUESSES THAT WERE NOT CORRECT..(J8)
(9) TOTAL ACCURATE GUESSES.........................(J7+J4)
(10) PERCENT ACCURATE GUESSES FOR PUPIL ID(J2).......(IA)

FIGURE 22 SIMPLIFIED FLOWCHART ILLIISTRATES COMPUTER PROGRAM TO PRINT PUPILS CORRECT (INCORRECT) RESPONSES TO UNIT TESTS


1
READ PATTERN OF CORRECT ITEMS I1(1)...I1(50)
2
READ LIST OF TEST ITEM GENERALIZATIONS I2(1,1)...I2(50,80)
3
READ AND PRINT: NAME OF CITY, SCHOOL, CLASS, GRADE I3(1)...I3(10)
4
READ AND PRINT: PUPIL'S NAME I4(1)...I4(10) PUPIL'S I.D. I6 PUPIL'S PATTERN OF CORRECT RESPONSES I5(1)...I5(50)
5
INITIALIZE J=0
6
PREPARE TO TEST FOR CORRECT RESPONSES TO ITEM J=J + 1
7
IS I1(J)-I4(J)=0 ?
YES
NO
8
WRITE ENGLISH STATEMENT CORRESPONDING TO CORRECT RESPONSE TO TEST ITEM PRINT: I2(J,1)...I2(J,80)
9
CHECK FOR LAST TEST ITEM: IS J_50?
YES
NO
GO TO 6
10
IS ANOTHER CLASS, SCHOOL, CITY TO BE PROCESSED? (IS I3=0?)
YES
GO TO 3
NO
GO TO 4

## Appendix H-1

## Table 177 FORMULAS USED IN STATISTICAL ANALYSIS OF DATA

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### Analysis of Variance (One Way)

ST. DEV.:

$$SD_i = \sqrt{\frac{\sum_{j=1}^{N_i} (X_{ij} - \overline{X})^2}{N_i - 1}}$$

where $SD_i$ is the standard deviation within group i $N_i$ is the number of observations in group i, $X_i$ is the mean for the variable $X_i$ in group i.

$$\text{Total SD} = \sqrt{\frac{\sum_{i=1}^{k} \sum_{j=1}^{N_i} (X_{ij} - \overline{X})^2}{N-1}}$$

where N is the total number of observations in the sample, $\overline{X}$ is the mean for the total sample for the variable X, and k is the number of groups.

ERROR SS:

$$SS_W = \sum_{j=1}^{k} \sum_{i=1}^{N_i} (X_i - \overline{X}_j)^2$$

where $SS_W$ is the sums of squares for within groups, k is the number of groups, $N_i$ is the number of observations in group j and $X_j$ is the mean for the variable X in group j.

TREATMENT SS:

$$SS_B = \sum_{j=1}^{k} N_j(X_j - \overline{X})^2$$

where $SS_B$ is the sum of squares for treatments, k is the number of groups, $N_j$ is the number of observations in group j, $X_j$ is the mean for the variable X in group j, and $\overline{X}$ is the mean for the total sample.

TOTAL SS:

$SS_T$ $SS_W$ $SS_T$ is the total sum of squares or the sum of the squared deviations from the general mean of all measures in all groups.

$$SS_T = \sum_{i=1}^{k} \sum_{j=1}^{N_i} (X_{ij} - \overline{X})^2$$

ERROR MS:

$MS_W = SS_W /N-k$ where $MS_W$ is the mean square for within groups, N is the total number of observations in the sample, and k is the number of treatment groups.

Table177 (Continued)

---

TREATMENT MS: $MS_B = SS_B/k-1$ where $MS_B$ is the mean square for treatments and k is the number of treatment groups.

F-TEST: $F = MS_B / MS_W$

T-TEST: $T = \sqrt{F}$ when there are only two treatment groups.

BARTLETTS TEST:
$$B = \frac{df_w\left(\log_e \sum ss_g - \log_e df_w\right) - \sum df_g \log_e s_g^2}{1 + (\sum 1/df_g - 1/df_w / (3g-3)}$$

where

df = degrees of freedom

w = within groups

g = groups

ss = sums of squares

$s^2$ = variance

Pearson Product Moment Correlation Analysis

CORRELATION COEFFICIENT:
$$r = \frac{N \sum XY - (\sum X)(\sum Y)}{\sqrt{[N \sum X^2 - (\sum X)^2][N \sum Y^2 - (\sum Y)^2]}}$$

where N is the number of observations having data for the calculation, and X and Y represent values of the variable being correlated.

Table 178 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FOURTH GRADE PUPILS' SCORES ON MACHINES TEST (M12) PRIOR TO INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #3 | 9 | 24 | 9.7 | 5.1 | Mid |
| Detroit #3 | 10 | 19 | 6.8 | 3.5 | Mid |
| Detroit #5 | 19 | 13 | 6.2 | 2.8 | Low |
| Detroit #5 | 20 | 21 | 6.3 | 2.8 | Low |
| Suburban #6 | 23 | 16 | 7.9 | 3.8 | Mid |
| Suburban #6 | 24 | 19 | 8.5 | 4.0 | Mid |
| Suburban #8 | 38 | 18 | 9.1 | 4.1 | High |
| Totals | | 130 | 7.9 | 4.0 | |

F= 2.5 with 6 and 123 df; F (.01 level)= 2.99 NOT SIGNIFICANT

Bartlett's Test= 9.95 with 6 df; Chi-square (.01 level)= 16.8 NOT SIGNIFICANT

Table 179 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FIFTH GRADE PUPILS' SCORES ON MACHINES TEST (M12) PRIOR TO INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 1 | 29 | 7.5 | 2.6 | Low |
| Detroit #1 | 2 | 26 | 11.9 | 4.7 | Low |
| Detroit #2 | 6 | 23 | 12.0 | 4.0 | Mid |
| Detroit #3 | 11 | 28 | 9.1 | 4.9 | Mid |
| Detroit #3 | 12 | 30 | 12.3 | 5.5 | Mid |
| Detroit #4 | 15 | 23 | 10.6 | 3.5 | Mid |
| Detroit #4 | 16 | 24 | 8.8 | 4.1 | Mid |
| Detroit #5 | 21 | 34 | 7.1 | 3.4 | Low |
| Suburban #6 | 25 | 15 | 12.0 | 4.3 | Mid |
| Suburban #6 | 26 | 19 | 9.7 | 4.9 | Mid |
| Suburban #7 | 32 | 27 | 12.0 | 5.6 | High |
| Suburban #7 | 33 | 30 | 9.0 | 4.1 | High |
| Suburban #7 | 34 | 21 | 10.6 | 3.5 | High |
| Suburban #8 | 39 | 20 | 13.1 | 5.9 | High |
| Totals | | 349 | 10.2 | 4.7 | |

F= 4.9 with 13 and 335 df; F(.01 level)= 2.28 SIGNIFICANT

Bartlett's Test= 31.31 with 13 df; Chi-square (.01 level)= 27.7 SIGNIFICANT

Table 180 RESULTS OF ANALYSIS OF VARIANCE TEST FOR SIXTH GRADE PUPILS' SCORES ON MACHINES TEST (M12) PRIOR TO INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 3 | 20 | 10.5 | 3.4 | Low |
| Detroit #1 | 4 | 18 | 11.3 | 2.9 | Low |
| Detroit #2 | 7 | 35 | 12.9 | 4.3 | Mid |
| Detroit #2 | 8 | 36 | 15.5 | 5.5 | Mid |
| Detroit #2 | 88 | 20 | 12.8 | 5.4 | Mid |
| Detroit #3 | 13 | 26 | 11.4 | 4.9 | Mid |
| Detroit #3 | 14 | 33 | 12.3 | 4.5 | Mid |
| Detroit #3 | 58 | 17 | 15.4 | 5.0 | Mid |
| Detroit #4 | 17 | 16 | 10.7 | 5.4 | Mid |
| Detroit #4 | 18 | 27 | 12.5 | 4.8 | Mid |
| Detroit #5 | 22 | 24 | 9.3 | 3.9 | Low |
| Suburban #6 | 27 | 23 | 12.0 | 3.8 | Mid |
| Suburban #6 | 28 | 34 | 14.9 | 4.9 | Mid |
| Suburban #7 | 35 | 23 | 11.9 | 4.7 | High |
| Suburban #7 | 36 | 23 | 11.9 | 5.9 | High |
| Suburban #7 | 37 | 26 | 12.4 | 4.8 | High |
| Suburban #8 | 40 | 25 | 13.7 | 5.6 | High |
| Suburban #8 | 41 | 20 | 13.2 | 5.6 | High |
| Totals | | 446 | 12.6 | 5.0 | |

F= 3.0 with 17 and 428 df; F(.01 level)= 2.04 SIGNIFICANT

Bartlett's Test= 21.89 with 17 df; Chi-square (.01 level)= 33.4 NOT SIGNIFICANT

Table 181 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FOURTH GRADE PUPILS' SCORES ON MACHINES TEST (M23) AFTER INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #3 | 9 | 20 | 15.5 | 6.7 | Mid |
| Detroit #3 | 10 | 20 | 8.7 | 5.4 | Mid |
| Detroit #5 | 19 | 11 | 9.4 | 5.0 | Low |
| Detroit #5 | 20 | 12 | 6.6 | 4.0 | Low |
| Suburban #6 | 23 | 18 | 10.4 | 3.5 | Mid |
| Suburban #6 | 24 | 20 | 12.2 | 5.4 | Mid |
| Suburban #8 | 38 | 20 | 14.1 | 6.7 | High |
| Totals | | 121 | 11.4 | 6.1 | |

F= 5.4 with 6 and 114 df; F(.01 level)= 2.99 SIGNIFICANT

Bartlett's Test= 10.35 with 6 df; Chi-square (.01 level)= 16.8 NOT SIGNIFICANT

Table 182 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FIFTH GRADE PUPILS' SCORES ON MACHINES TEST (M23) PRIOR TO INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 1 | 9 | 8.3 | 3.0 | Low |
| Detroit #1 | 2 | 27 | 13.1 | 7.2 | Low |
| Detroit #2 | 6 | 22 | 16.3 | 5.1 | Mid |
| Detroit #3 | 11 | 25 | 13.6 | 5.4 | Mid |
| Detroit #3 | 12 | 28 | 17.1 | 6.4 | Mid |
| Detroit #4 | 15 | 15 | 16.5 | 8.3 | Mid |
| Detroit #4 | 16 | 21 | 10.1 | 5.4 | Mid |
| Detroit #5 | 21 | 13 | 10.5 | 4.8 | Low |
| Suburban #6 | 25 | 15 | 15.7 | 3.2 | Mid |
| Suburban #6 | 26 | 19 | 14.6 | 6.6 | Mid |
| Suburban #7 | 32 | 29 | 18.9 | 7.5 | High |
| Suburban #7 | 33 | 27 | 14.4 | 6.3 | High |
| Suburban #7 | 34 | 21 | 14.6 | 6.2 | High |
| Suburban #8 | 39 | 23 | 17.3 | 7.1 | High |
| Totals | | 294 | 14.8 | 6.7 | |

F= 4.1 with 13 and 280 df; F(.01 level)= 2.28 SIGNIFICANT

Bartlett's Test= 25.66 with 13 df; Chi-square (.01 level)= 27.7 NOT SIGNIFICANT

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Table 183 RESULTS OF ANALYSIS OF VARIANCE TEST FOR SIXTH GRADE PUPILS' SCORES ON MACHINES TEST (M23) PRIOR TO INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 3 | 25 | 9.9 | 4.2 | Low |
| Detroit #1 | 4 | 19 | 10.3 | 5.2 | Low |
| Detroit #2 | 7 | 35 | 17.7 | 6.3 | Mid |
| Detroit #2 | 8 | 35 | 19.3 | 6.6 | Mid |
| Detroit #2 | 88 | 18 | 16.4 | 6.4 | Mid |
| Detroit #3 | 13 | 27 | 16.7 | 6.6 | Mid |
| Detroit #3 | 14 | 26 | 16.4 | 5.6 | Mid |
| Detroit #3 | 58 | 16 | 23.0 | 6.8 | Mid |
| Detroit #4 | 17 | 16 | 14.3 | 9.6 | Mid |
| Detroit #4 | 18 | 17 | 13.7 | 6.6 | Mid |
| Suburban #6 | 27 | 24 | 17.1 | 6.0 | Mid |
| Suburban #6 | 28 | 20 | 17.0 | 4.7 | Mid |
| Suburban #7 | 35 | 25 | 17.9 | 7.2 | High |
| Suburban #7 | 36 | 25 | 18.3 | 7.0 | High |
| Suburban #7 | 37 | 26 | 17.0 | 7.4 | High |
| Suburban #8 | 40 | 27 | 18.6 | 6.6 | High |
| Suburban #8 | 41 | 27 | 15.6 | 9.3 | High |
| Totals | | 408 | 16.6 | 7.1 | |

F 4.6 with 16 and 391 df; F(.01 level) 2.04 SIGNIFICANT

Bartlett's Test 28.68 with 16 df; Chi-square (.01 level) 32.0 NOT SIGNIFICANT

Table 184 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FOURTH GRADE PUPILS' SCORES ON ELECTRICITY TEST (E12) PRIOR TO INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #3 | 9 | 18 | 8.6 | 5.6 | Mid |
| Detroit #3 | 10 | 18 | 5.9 | 3.4 | Mid |
| Detroit #5 | 19 | 17 | 4.1 | 2.2 | Low |
| Detroit #5 | 20 | 15 | 3.8 | 2.8 | Low |
| Suburban #6 | 23 | 22 | 6.9 | 3.3 | Mid |
| Suburban #6 | 24 | 25 | 5.8 | 2.8 | Mid |
| Suburban #8 | 38 | 23 | 7.9 | 4.8 | High |
| Totals |  | 138 | 6.3 | 4.0 |  |

F= 4.1 with 6 and 131 df; F (.01 level)= 2.95 SIGNIFICANT

Bartlett's Test= 22.86 with 6 df; Chi-square (.01 level)= 16.8 SIGNIFICANT

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Table 185 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FIFTH GRADE PUPILS' SCORES ON ELECTRICITY TEST (E12) PRIOR TO INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 2 | 24 | 6.8 | 4.4 | Low |
| Detroit #2 | 6 | 24 | 9.1 | 3.5 | Mid |
| Detroit #3 | 11 | 20 | 9.5 | 4.6 | Mid |
| Detroit #3 | 12 | 26 | 8.7 | 5.6 | Mid |
| Detroit #4 | 15 | 14 | 11.6 | 6.3 | Mid |
| Detroit #4 | 16 | 25 | 7.3 | 5.2 | Mid |
| Detroit #5 | 21 | 12 | 4.3 | 2.1 | Low |
| Suburban #6 | 25 | 25 | 9.2 | 4.3 | Mid |
| Suburban #6 | 26 | 22 | 9.1 | 5.5 | Mid |
| Suburban #7 | 32 | 26 | 9.8 | 4.7 | High |
| Suburban #7 | 33 | 19 | 8.2 | 4.1 | High |
| Suburban #7 | 34 | 21 | 7.4 | 4.7 | High |
| Suburban #8 | 39 | 21 | 7.1 | 3.6 | High |
| Totals | | 279 | 8.4 | 4.8 | |

F= 2.4 with 12 and 266 df; F (.01 level)= 2.28 SIGNIFICANT

Bartlett's Test= 21.20 with 12 df; Chi-square (.01 level)= 26.2 NOT SIGNIFICANT

Table 186 RESULTS OF ANALYSIS OF VARIANCE TEST FOR SIXTH GRADE PUPILS' SCORES ON ELECTRICITY TEST (E12) PRIOR TO INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 3 | 12 | 7.5 | 3.5 | Low |
| Detroit #1 | 4 | 23 | 7.1 | 3.8 | Low |
| Detroit #2 | 7 | 30 | 5.9 | 4.7 | Mid |
| Detroit #2 | 8 | 34 | 9.7 | 6.0 | Mid |
| Detroit #3 | 13 | 26 | 10.3 | 6.0 | Mid |
| Detroit #3 | 14 | 24 | 10.2 | 5.3 | Mid |
| Detroit #3 | 58 | 14 | 15.9 | 7.3 | Mid |
| Detroit #4 | 17 | 13 | 6.9 | 5.6 | Mid |
| Detroit #4 | 18 | 14 | 9.1 | 5.7 | Mid |
| Suburban #6 | 27 | 21 | 9.7 | 5.4 | Mid |
| Suburban #6 | 28 | 22 | 10.4 | 4.3 | Mid |
| Suburban #7 | 35 | 16 | 13.4 | 5.5 | High |
| Suburban #7 | 36 | 19 | 10.7 | 3.6 | High |
| Suburban #7 | 37 | 19 | 11.2 | 5.2 | High |
| Suburban #8 | 40 | 27 | 12.1 | 6.4 | High |
| Suburban #8 | 41 | 26 | 15.9 | 7.3 | High |
| Totals | | 340 | 9.7 | 5.7 | |

F= 4.5 with 15 and 324 df; F (.01 level)= 2.17 SIGNIFICANT

Bartlett's Test= 22.0 with 15 df; Chi-square (.01 level)= 30.6 NOT SIGNIFICANT

Table 187 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FOURTH GRADE PUPILS' SCORES ON ELECTRICITY TEST (E23) AFTER INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #3 | 9 | 24 | 10.8 | 8.0 | Mid |
| Detroit #3 | 10 | 23 | 7.4 | 5.0 | Mid |
| Detroit #5 | 19 | 30 | 4.9 | 3.2 | Low |
| Detroit #5 | 20 | 22 | 4.7 | 3.0 | Low |
| Suburban #6 | 23 | 22 | 9.7 | 3.9 | Mid |
| Suburban #6 | 24 | 25 | 9.2 | 4.3 | Mid |
| Suburban #8 | 38 | 27 | 9.8 | 4.8 | High |
| Totals | | 173 | 8.0 | 5.3 | |

F= 6.6 with 6 and 166 df; F (.01 level)= 2.99 SIGNIFICANT

Bartlett's Test= 33.39 with 6 df; Chi-square (.01 level)= 16.8 SIGNIFICANT

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Table 188 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FIFTH GRADE PUPILS' SCORES ON ELECTRICITY TEST (E23) AFTER INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 2 | 25 | 9.5 | 8.4 | Low |
| Detroit #2 | 6 | 24 | 13.2 | 6.2 | Mid |
| Detroit #2 | 55 | 13 | 11.1 | 4.1 | Mid |
| Detroit #3 | 11 | 20 | 12.9 | 7.5 | Mid |
| Detroit #3 | 12 | 25 | 15.3 | 8.5 | Mid |
| Detroit #4 | 15 | 21 | 14.2 | 8.9 | Mid |
| Detroit #4 | 16 | 20 | 11.2 | 7.5 | Mid |
| Detroit #5 | 21 | 28 | 7.4 | 3.7 | Low |
| Suburban #6 | 25 | 18 | 10.5 | 6.7 | Mid |
| Suburban #6 | 26 | 23 | 12.3 | 7.9 | Mid |
| Suburban #7 | 32 | 26 | 13.9 | 8.0 | High |
| Suburban #7 | 33 | 25 | 11.6 | 6.7 | High |
| Suburban #7 | 34 | 22 | 11.6 | 6.0 | High |
| Suburban #8 | 39 | 24 | 10.1 | 4.7 | High |
| Totals | | 314 | 11.8 | 7.2 | |

F= 2.2 with 13 and 300 df; F (.01 level)= 2.28 NOT SIGNIFICANT

Bartlett's Test= 35.49 with 13 df; Chi-square (.01 level)= 27.7 SIGNIFICANT

Table 189 RESULTS OF ANALYSIS OF VARIANCE TEST FOR SIXTH GRADE PUPILS' SCORES ON ELECTRICITY TEST (E23) AFTER INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 3 | 17 | 5.4 | 3.9 | Low |
| Detroit #1 | 4 | 20 | 8.0 | 4.1 | Low |
| Detroit #2 | 7 | 35 | 13.2 | 7.4 | Mid |
| Detroit #2 | 8 | 33 | 14.8 | 6.6 | Mid |
| Detroit #3 | 13 | 24 | 15.0 | 9.2 | Mid |
| Detroit #3 | 14 | 26 | 15.0 | 6.0 | Mid |
| Detroit #3 | 58 | 29 | 16.6 | 9.1 | Mid |
| Detroit #4 | 17 | 14 | 12.4 | 9.3 | Mid |
| Detroit #4 | 18 | 20 | 14.4 | 7.8 | Mid |
| Detroit #5 | 22 | 26 | 6.2 | 3.4 | Low |
| Suburban #6 | 27 | 21 | 16.0 | 7.7 | Mid |
| Suburban #6 | 28 | 23 | 14.7 | 6.6 | Mid |
| Suburban #7 | 35 | 19 | 19.0 | 8.6 | High |
| Suburban #7 | 36 | 21 | 14.3 | 7.1 | High |
| Suburban #7 | 37 | 21 | 18.0 | 10.6 | High |
| Suburban #8 | 40 | 27 | 14.1 | 8.0 | High |
| Suburban #8 | 41 | 31 | 9.9 | 6.3 | High |
| Totals | | 407 | 13.4 | 8.1 | |

F= 6.0 with 16 and 390 df; F (.01 level)= 2.09 SIGNIFICANT

Bartlett's Test= 57.22 with 16 df; Chi-square (.01 level)= 32.0 SIGNIFICANT

Table 190 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FOURTH GRADE PUPILS' SCORES ON HEAT TEST (H12) PRIOR TO INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #3 | 9 | 29 | 12.9 | 6.7 | Mid |
| Detroit #3 | 10 | 21 | 9.4 | 6.7 | Mid |
| Detroit #5 | 19 | 31 | 5.5 | 3.9 | Low |
| Detroit #5 | 20 | 24 | 7.5 | 3.7 | Low |
| Suburban #6 | 23 | 25 | 11.5 | 4.6 | Mid |
| Suburban #6 | 24 | 25 | 10.6 | 4.6 | Mid |
| Suburban #8 | 38 | 24 | 11.3 | 5.9 | High |
| Totals | | 179 | 9.8 | 5.7 | |

F= 2.99 with 6 and 172 df; F (.01 level)= 2.99 SIGNIFICANT

Bartlett's Test= 17.54 with 6 df; Chi-square (.01 level)= 16.8 SIGNIFICANT

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Table 191 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FIFTH GRADE PUPILS' SCORES ON HEAT TEST (H12) PRIOR TO INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 2 | 27 | 10.7 | 5.9 | Low |
| Detroit #2 | 6 | 21 | 12.7 | 3.8 | Mid |
| Detroit #3 | 11 | 24 | 13.7 | 6.7 | Mid |
| Detroit #3 | 12 | 25 | 16.1 | 5.7 | Mid |
| Detroit #4 | 15 | 23 | 13.8 | 5.5 | Mid |
| Detroit #4 | 16 | 27 | 10.3 | 5.5 | Mid |
| Detroit #5 | 21 | 35 | 11.1 | 5.8 | Low |
| Suburban #6 | 25 | 20 | 14.4 | 5.2 | Mid |
| Suburban #6 | 28 | 20 | 15.2 | 7.0 | Mid |
| Suburban #7 | 32 | 29 | 14.4 | 5.9 | High |
| Suburban #7 | 33 | 33 | 13.9 | 4.9 | High |
| Suburban #7 | 34 | 26 | 14.2 | 5.8 | High |
| Suburban #8 | 39 | 26 | 12.8 | 6.4 | High |
| Totals | | 336 | 12.5 | 5.7 | |

F= 2.5 with 12 and 322 df; F(.01 level)= 2.28 SIGNIFICANT

Bartlett's Test= 10.97 with 12 df; Chi-square (.01 level)= 26.2 NOT SIGNIFICANT

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Table 192 RESULTS OF ANALYSIS OF VARIANCE TEST FOR SIXTH GRADE PUPILS' SCORES ON HEAT TEST (H12) PRIOR TO INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 3 | 23 | 7.8 | 4.9 | Low |
| Detroit #1 | 4 | 25 | 8.1 | 4.4 | Low |
| Detroit #2 | 7 | 38 | 11.5 | 6.3 | Mid |
| Detroit #2 | 8 | 34 | 16.2 | 6.0 | Mid |
| Detroit #3 | 13 | 29 | 18.2 | 6.5 | Mid |
| Detroit #3 | 14 | 29 | 15.5 | 6.0 | Mid |
| Detroit #3 | 58 | 30 | 17.3 | 6.4 | Mid |
| Detroit #4 | 17 | 27 | 12.1 | 5.5 | Mid |
| Detroit #4 | 18 | 24 | 12.6 | 4.8 | Mid |
| Suburban #6 | 27 | 22 | 13.7 | 4.2 | Mid |
| Suburban #6 | 28 | 26 | 13.8 | 5.7 | Mid |
| Suburban #7 | 35 | 24 | 16.9 | 7.1 | High |
| Suburban #7 | 36 | 27 | 16.1 | 5.3 | High |
| Suburban #7 | 37 | 24 | 17.0 | 6.7 | High |
| Suburban #8 | 40 | 29 | 17.5 | 6.9 | High |
| Suburban #8 | 41 | 29 | 13.0 | 7.5 | High |
| Totals |  | 440 | 14.3 | 6.7 |  |

F= 7.6 with 15 and 424 df; F (.01 level)= 2.12 SIGNIFICANT

Bartlett's Test= 20.01 with 15 df; Chi-square (.01 level)= 30.6 NOT SIGNIFICANT

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Table 193 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FOURTH GRADE PUPILS' SCORES ON HEAT TEST (H23) AFTER INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #3 | 9 | 30 | 17.7 | 7.9 | Mid |
| Detroit #3 | 10 | 20 | 12.4 | 8.2 | Mid |
| Detroit #5 | 19 | 19 | 6.6 | 6.4 | Low |
| Detroit #5 | 20 | 13 | 6.6 | 6.0 | Low |
| Suburban #6 | 23 | 21 | 12.9 | 5.9 | Mid |
| Suburban #6 | 24 | 20 | 12.5 | 5.9 | Mid |
| Suburban #8 | 38 | 16 | 13.6 | 6.4 | High |
| Totals |  | 139 | 12.4 | 7.6 |  |

F= 7.06 with 6 and 132 df; F(.01 level)= 2.99 SIGNIFICANT

Bartlett's Test= 7.66 with 6 df; Chi-square (.01 level)= 16.8 NOT SIGNIFICANT

Table 194 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FIFTH GRADE PUPILS' SCORES ON HEAT TEST (H23) AFTER INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 2 | 23 | 13.0 | 8.1 | Low |
| Detroit #2 | 6 | 19 | 17.8 | 5.4 | Mid |
| Detroit #3 | 11 | 22 | 16.1 | 7.1 | Mid |
| Detroit #3 | 12 | 23 | 19.7 | 8.8 | Mid |
| Detroit #4 | 15 | 22 | 15.9 | 4.3 | Mid |
| Detroit #4 | 16 | 27 | 11.5 | 5.7 | Mid |
| Detroit #5 | 21 | 24 | 12.3 | 6.5 | Low |
| Suburban #6 | 25 | 21 | 15.1 | 6.7 | Mid |
| Suburban #6 | 26 | 18 | 19.4 | 7.8 | Mid |
| Suburban #7 | 32 | 31 | 18.7 | 7.7 | High |
| Suburban #7 | 33 | 33 | 17.1 | 6.9 | High |
| Suburban #7 | 34 | 24 | 15.6 | 7.9 | High |
| Suburban #8 | 39 | 19 | 17.9 | 10.2 | High |
| Totals | | 306 | 16.2 | 7.6 | |

F= 3.1 with 12 and 292 df; F (.01 level)= 2.28 SIGNIFICANT

Bartlett's Test= 22.97 with 12 df; Chi-square (.01 level)= 26.2 NOT SIGNIFICANT

Table 195 RESULTS OF ANALYSIS OF VARIANCE TEST FOR SIXTH GRADE PUPILS' SCORES ON HEAT TEST (H23) AFTER INSTRUCTION

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #2 | 7 | 34 | 18.4 | 8.3 | Mid |
| Detroit #2 | 8 | 31 | 19.3 | 6.9 | Mid |
| Detroit #3 | 13 | 25 | 21.1 | 8.5 | Mid |
| Detroit #3 | 14 | 24 | 18.4 | 6.5 | Mid |
| Detroit #3 | 58 | 27 | 21.5 | 9.0 | Mid |
| Detroit #4 | 17 | 28 | 13.5 | 7.0 | Mid |
| Detroit #4 | 18 | 26 | 17.4 | 5.9 | Mid |
| Suburban #6 | 27 | 21 | 20.0 | 6.6 | Mid |
| Suburban #6 | 28 | 22 | 17.8 | 6.0 | Mid |
| Suburban #7 | 35 | 22 | 20.3 | 7.6 | High |
| Suburban #7 | 36 | 23 | 18.6 | 7.0 | High |
| Suburban #7 | 37 | 21 | 20.6 | 7.2 | High |
| Suburban #8 | 40 | 27 | 21.5 | 8.3 | High |
| Suburban #8 | 41 | 28 | 17.9 | 8.1 | High |
| Totals | | 359 | 19.0 | 7.4 | |

F= 3.4 with 13 and 343 df; F (.01 level)= 2.17 SIGNIFICANT

Bartlett's Test= 13.74 with 13 df; Chi-square (.01 level)= 27.7 NOT SIGNIFICANT

Table 196 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FOURTH GRADE PUPILS' SCORES ON READING COMPREHENSION TEST

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #3 | 9 | 25 | 4.3 | 1.7 | Mid |
| Detroit #3 | 10 | 23 | 3.6 | 1.0 | Mid |
| Detroit #5 | 19 | 22 | 3.0 | 1.2 | Low |
| Detroit #5 | 20 | 35 | 2.3 | .6 | Low |
| Suburban #6 | 23 | 24 | 3.1 | .8 | Mid |
| Suburban #6 | 24 | 25 | 3.7 | .7 | Mid |
| Suburban #8 | 38 | 25 | 4.2 | 1.6 | High |
| Totals |  | 179 | 3.4 | 1.3 |  |

F= 11.3 with 6 and 172 df; F (.01 level)= 2.92 SIGNIFICANT

Bartlett's Test= 44.49 with 6 df; Chi-square (.01 level)= 16.8 SIGNIFICANT

Table 197 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FOURTH GRADE PUPILS' SCORES ON STANDARDIZED SCIENCE ACHIEVEMENT TEST

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #3 | 9 | 23 | 5.6 | 1.8 | Mid |
| Detroit #3 | 10 | 21 | 4.7 | 1.5 | Mid |
| Detroit #5 | 19 | 20 | 4.0 | 1.4 | Low |
| Detroit #5 | 20 | 30 | 3.1 | .8 | Low |
| Suburban #6 | 23 | 25 | 4.4 | .9 | Mid |
| Suburban #6 | 24 | 27 | 4.0 | .7 | Mid |
| Suburban #8 | 38 | 24 | 4.7 | 1.3 | High |
| Totals | | 170 | 4.3 | 1.4 | |

F= 10.27 with 6 and 163 df; F (.01 level)= 2.92 SIGNIFICANT

Bartlett's Test= 37.77 with 6 df; Chi-square (.01 level)= 16.8 SIGNIFICANT

**Table 198** RESULTS OF ANALYSIS OF VARIANCE TEST FOR FOURTH GRADE PUPILS' SCORES ON VERBAL INTELLIGENCE TEST

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #3 | 9 | 16 | 110.6 | 12.8 | Mid |
| Detroit #3 | 10 | 20 | 100.3 | 11.8 | Mid |
| Detroit #5 | 19 | 13 | 98.8 | 14.3 | Low |
| Detroit #5 | 20 | 23 | 83.6 | 11.0 | Low |
| Suburban #6 | 23 | 20 | 105.8 | 12.8 | Mid |
| Suburban #6 | 24 | 22 | 107.0 | 9.5 | Mid |
| Suburban #8 | 38 | 23 | 112.4 | 15.4 | High |
| Totals |  | 137 | 102.4 | 15.4 |  |

F= 13.57 with 6 and 130 df; F (.01 level)= 2.95 SIGNIFICANT

Bartlett's Test= 4.68 with 6 df; Chi-square (.01 level)= 16.8 NOT SIGNIFICANT

### Table 199 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FIFTH GRADE PUPILS' SCORES ON READING COMPREHENSION TEST

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 1 | 34 | 3.2 | .8 | Low |
| Detroit #1 | 2 | 29 | 5.0 | 1.6 | Low |
| Detroit #2 | 6 | 28 | 5.1 | 1.1 | Mid |
| Detroit #3 | 11 | 30 | 4.8 | 1.5 | Mid |
| Detroit #3 | 12 | 31 | 4.7 | 1.7 | Mid |
| Detroit #4 | 15 | 18 | 5.2 | 1.8 | Mid |
| Detroit #4 | 16 | 34 | 4.3 | 1.7 | Mid |
| Detroit #5 | 21 | 40 | 2.8 | .9 | Low |
| Suburban #6 | 25 | 26 | 4.6 | 1.1 | Mid |
| Suburban #6 | 26 | 24 | 5.0 | 1.5 | Mid |
| Suburban #7 | 33 | 22 | 5.3 | 1.6 | High |
| Suburban #7 | 34 | 21 | 5.2 | 1.3 | High |
| Suburban #8 | 39 | 33 | 5.1 | 2.1 | High |
| Totals |  | 370 | 4.6 | 1.4 |  |

F= 8.5 with 12 and 355 df; F (.01 level)= 2.25 SIGNIFICANT

Bartlett's Test= 54.14 with 12 df; Chi-square (.01 level)= 26.2 SIGNIFICANT

Table 200 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FIFTH GRADE PUPILS' SCORES ON STANDARDIZED SCIENCE ACHIEVEMENT TEST

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 1 | 34 | 4.0 | .9 | Low |
| Detroit #1 | 2 | 28 | 5.5 | 1.7 | Low |
| Detroit #2 | 5 | 48 | 6.3 | 1.1 | Mid |
| Detroit #2 | 6 | 25 | 6.0 | 1.3 | Mid |
| Detroit #3 | 11 | 29 | 5.5 | 1.1 | Mid |
| Detroit #3 | 12 | 28 | 5.5 | 1.4 | Mid |
| Detroit #4 | 15 | 16 | 6.5 | 1.7 | Mid |
| Detroit #4 | 16 | 32 | 5.6 | 1.9 | Mid |
| Detroit #5 | 21 | 43 | 3.8 | 1.2 | Low |
| Suburban #6 | 25 | 22 | 5.8 | 1.5 | Mid |
| Suburban #6 | 26 | 25 | 6.0 | 1.7 | Mid |
| Suburban #7 | 32 | 29 | 6.4 | 1.6 | High |
| Suburban #7 | 33 | 23 | 6.2 | 1.2 | High |
| Suburban #7 | 34 | 22 | 6.3 | 1.5 | High |
| Suburban #8 | 39 | 29 | 5.8 | 1.9 | High |
| Totals | | 433 | 5.6 | 1.7 | |

F= 10.2 with 14 and 418 df; F (.01 level)= 2.12 SIGNIFICANT

Bartlett's Test = 41.19 with 14 df; Chi-square (.01 level)= 29.1 SIGNIFICANT

Table 201 RESULTS OF ANALYSIS OF VARIANCE TEST FOR FIFTH GRADE PUPILS' SCORES ON VERBAL INTELLIGENCE TEST

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 1 | 31 | 84.9 | 11.2 | Low |
| Detroit #1 | 2 | 27 | 105.7 | 13.5 | Low |
| Detroit #2 | 5 | 49 | 116.4 | 11.6 | Mid |
| Detroit #2 | 6 | 28 | 111.5 | 13.0 | Mid |
| Detroit #3 | 11 | 22 | 109.7 | 12.6 | Mid |
| Detroit #3 | 12 | 25 | 107.6 | 16.0 | Mid |
| Detroit #4 | 15 | 29 | 109.3 | 16.2 | Mid |
| Detroit #4 | 16 | 29 | 96.0 | 14.3 | Mid |
| Detroit #5 | 21 | 22 | 86.2 | 12.1 | Low |
| Suburban #6 | 25 | 24 | 108.8 | 12.5 | Mid |
| Suburban #6 | 26 | 23 | 104.9 | 11.5 | Mid |
| Suburban #7 | 32 | 27 | 118.6 | 12.6 | High |
| Suburban #7 | 33 | 21 | 113.5 | 13.4 | High |
| Suburban #7 | 34 | 23 | 114.5 | 11.9 | High |
| Suburban #8 | 39 | 27 | 109.1 | 16.0 | High |
| Totals | | 407 | 106.8 | 16.4 | |

F= 16.0 with 14 and 392 df; F (.01 level)= 2.10 SIGNIFICANT

Bartlett's Test= 12.06 with 14 df; Chi-square (.01 level)= 29.1 NOT SIGNIFICANT

Table 202 RESULTS OF ANALYSIS OF VARIANCE TEST FOR SIXTH GRADE PUPILS' SCORES ON READING COMPREHENSION TEST

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 3 | 31 | 3.7 | .9 | Low |
| Detroit #1 | 4 | 27 | 4.3 | .9 | Low |
| Detroit #2 | 7 | 36 | 6.2 | 1.9 | Mid |
| Detroit #2 | 8 | 63 | 6.3 | 1.4 | Mid |
| Detroit #3 | 13 | 29 | 5.7 | 1.8 | Mid |
| Detroit #3 | 14 | 36 | 6.4 | 1.8 | Mid |
| Detroit #3 | 58 | 18 | 7.0 | 1.7 | Mid |
| Detroit #4 | 17 | 20 | 5.8 | 1.7 | Mid |
| Detroit #4 | 18 | 30 | 6.4 | 2.4 | Mid |
| Detroit #5 | 22 | 24 | 4.2 | 1.6 | Low |
| Suburban #6 | 27 | 25 | 5.6 | 1.7 | Mid |
| Suburban #6 | 28 | 33 | 5.8 | 1.7 | Mid |
| Suburban #7 | 35 | 25 | 6.1 | 1.7 | High |
| Suburban #7 | 36 | 20 | 5.3 | 1.2 | High |
| Suburban #7 | 37 | 20 | 6.1 | 2.1 | High |
| Suburban #8 | 40 | 30 | 6.3 | 1.6 | High |
| Suburban #8 | 41 | 30 | 6.4 | 1.7 | High |
| Totals | | 497 | 5.8 | 1.9 | |

F= 8.2 with 16 and 480 df; F (.01 level)= 2.04 SIGNIFICANT

Bartlett's Test= 46.15 with 16 df; Chi-square (.01 level)= 32.0 SIGNIFICANT

## Table 203 RESULTS OF ANALYSIS OF VARIANCE TEST FOR SIXTH GRADE PUPILS' SCORES ON STANDARDIZED SCIENCE ACHIEVEMENT TEST

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 3 | 30 | 4.0 | 1.2 | Low |
| Detroit #1 | 4 | 26 | 4.6 | 1.2 | Low |
| Detroit #2 | 7 | 35 | 6.9 | 1.6 | Mid |
| Detroit #2 | 8 | 57 | 7.3 | 1.8 | Mid |
| Detroit #3 | 13 | 28 | 6.6 | 2.0 | Mid |
| Detroit #3 | 14 | 31 | 6.9 | 1.8 | Mid |
| Detroit #3 | 58 | 18 | 7.6 | 2.2 | Mid |
| Detroit #4 | 17 | 19 | 5.3 | 1.8 | Mid |
| Detroit #4 | 18 | 25 | 6.7 | 2.4 | Mid |
| Detroit #5 | 22 | 54 | 4.6 | 1.2 | Low |
| Suburban #6 | 27 | 23 | 6.4 | 1.7 | Mid |
| Suburban #6 | 28 | 34 | 7.1 | 1.3 | Mid |
| Suburban #7 | 35 | 22 | 6.9 | 1.8 | High |
| Suburban #7 | 36 | 21 | 6.7 | 1.5 | High |
| Suburban #7 | 37 | 20 | 6.9 | 1.6 | High |
| Suburban #8 | 40 | 28 | 6.1 | 1.6 | High |
| Suburban #8 | 41 | 29 | 6.5 | 1.9 | High |
| Totals | | 500 | 6.3 | 2.0 | |

F= 13.1 with 16 and 483 df; F (.01 level)= 2.04 SIGNIFICANT

Bartlett's Test= 37.40 with 16 df; Chi-square (.01 level)= 32.0 SIGNIFICANT

Table 204 RESULTS OF ANALYSIS OF VARIANCE TEST FOR SIXTH GRADE PUPILS' SCORES ON VERBAL INTELLIGENCE TEST

| School | Class No. | No. Pupils | Mean | Stand. Dev. | Soc-Econ. Level |
|---|---|---|---|---|---|
| Detroit #1 | 3 | 26 | 86.0 | 7.9 | Low |
| Detroit #1 | 4 | 25 | 92.8 | 12.4 | Low |
| Detroit #2 | 7 | 36 | 111.4 | 16.5 | Mid |
| Detroit #2 | 8 | 58 | 104.4 | 12.6 | Mid |
| Detroit #3 | 13 | 24 | 106.6 | 15.6 | Mid |
| Detroit #3 | 14 | 26 | 105.5 | 13.4 | Mid |
| Detroit #4 | 17 | 15 | 96.5 | 15.9 | Mid |
| Detroit #4 | 18 | 27 | 102.8 | 15.6 | Mid |
| Detroit #5 | 22 | 26 | 87.4 | 14.3 | Low |
| Suburban #6 | 27 | 25 | 105.3 | 16.5 | Mid |
| Suburban #6 | 28 | 32 | 109.8 | 13.0 | Mid |
| Suburban #7 | 35 | 24 | 114.0 | 13.6 | High |
| Suburban #7 | 36 | 19 | 115.5 | 10.8 | High |
| Suburban #7 | 37 | 19 | 111.9 | 15.1 | High |
| Suburban #8 | 40 | 29 | 112.4 | 12.1 | High |
| Suburban #8 | 41 | 31 | 108.9 | 10.9 | High |
| Totals |  | 442 | 104.6 | 15.8 |  |

F= 11.4 with 15 and 426 df; F(.01 level)= 2.12 SIGNIFICANT

Bartlett's Test= 24.75 with 15 df; Chi-square (.01 level)= 30.58 NOT SIGNIFICANT

## H-30

## Graphical Analysis of Class Scores

A. Distributions of Scores. There were three major types of distributions which seemed to characterize each class distribution of scores on the pre-test and on the post-test. The normal distribution occurred most frequently. For these classes, there was a symmetric arrangement of scores about a mean equal to zero and a standard deviation equal to one. In this distribution the vertical axis was scaled in equal units, indicating the number of correct responses to the test. The horizontal axis was expressed in equal units of standard deviation. Figure 4 shows a typical graph using normal probability paper.

For curves with a log-normal distribution, the vertical axis was scaled in equal units of the log of the number of correct responses. This indicated an exponential increase in the magnitude of correct responses to the test. The horizontal axis was expressed in equal units of standard deviation. This arrangement is typically plotted on semi-log paper.

For classes where the distribution was skewed, this indicated an asymmetric distribution in which the majority of scores accumulated in the low region (positively skewed) or the high region (negatively skewed) of the horizontal axis. Gumbel's ( 26) skewed probability distribution and Powell's ( 62) skewed probability paper (Figure 5) have been used to plot test data which follow a skewed distribution. In the skewed distribution, the vertical axis may be scaled in equal units of correct responses to the test or it may also be scaled in equal units of the log of the number of correct responses. The horizontal axis is scaled in equal units of standard deviation using Gumbel's distribution.

B. Changes in Distribution of Scores Within Classes. Table 205 indicates changes which might occur in the distribution of scores obtained for the pre-test and for the post-test. There were nine distributions which occured frequently within the classes and they have been indicated in that table, although other variations could be identified. The normal distribution on the pre-test followed by a normal distribution on the post-test has been indicated by the expression (N-N). It suggests that the distribution of scores was unchanged by instruction and remained symmetric about the mean score.

A normal distribution on the pre-test and a log-normal distribution on the post-test is indicated by the expression (N-LN). The log-normal distribution indicates that the rate of improvement is exponential and is symmetric about the log of the mean score.

Among other things, it indicates that the constant rate of change produced substantially higher raw scores for those pupils scoring above the median than those pupils who scored below the median.

Classes having a normal distribution on the pre-test and a positively or negatively skewed distribution on the post-test are indicated by the expression (N-S). This indicates a symmetric distribution before instruction, and a skewed distribution after instruction in which many pupils made low scores (positively skewed) or many pupils made high scores (negatively skewed) after instruction.

When a class has a normal distribution about the log of the mean score on the pre-test and a normal distribution about the arithmetic mean score on the post-test, this is indicated by the expression (LN-N). This suggests that pupils differed substantially in the amount of information or preparation which they brought to instruction, as indicated by their exponential rate of change on the pre-test. However, after instruction the regression effect is illustrated in the establishment of a normal distribution which is symmetric about the arithmetic mean score.

If a class has a normal distribution of scores about the log of the mean score on the pre-test and also has a normal distribution about the log of the mean score on the post-test, this is indicated by the expression (LN-LN). This indicates that pupils in the same class differed substantially in the amount of information or preparation which they brought to instruction (exponential rate of increase); and this disparity continued after instruction had concluded.

If a class has a normal distribution of scores about the log of the mean score on the pre-test and a skewed distribution on the post-test, this condition is represented by (LN-S). This suggests that there was a substantial difference in the amount of information or preparation which pupils brought to instruction, and this difference increased sharply if the distribution is negatively skewed or it regressed sharply if the distribution is positively skewed.

If a class has a skewed distribution of scores on the pre-test and a normal distribution of scores on the post-test, this is indicated by the expression (S-N). This change indicated a shift from very high scores to lower scores or from low scores to relatively higher scores, depending upon whether the initial distribution was negatively or positively skewed.

H-32

### Table 205 POSSIBLE CHANGES IN PATTERN OF DISTRIBUTION FROM PRE-TEST TO POST-TEST

| Pattern on Pre-Test Graph | Pattern on Post-Test Graph<br>Normal (N) | <br>Log Normal (LN) | <br>Skewed (S) |
|---|---|---|---|
| Normal (N) | (N-N) | (N-LN) | (N-S) |
| Log Normal (LN) | (LN-N) | (LN-LN) | (LN-S) |
| Skewed (S) | (S-N) | (S-LN) | (S-S) |

If a class has a distribution which is skewed on the pre-test and a log-normal distribution on the post-test, this is indicated by the expression (S-LN). This suggests that there was a substantial change in the distribution of scores from low scores (positively skewed distribution) to log normal distribution. It could also suggest a regression effect if the skewed distribution was negatively skewed.

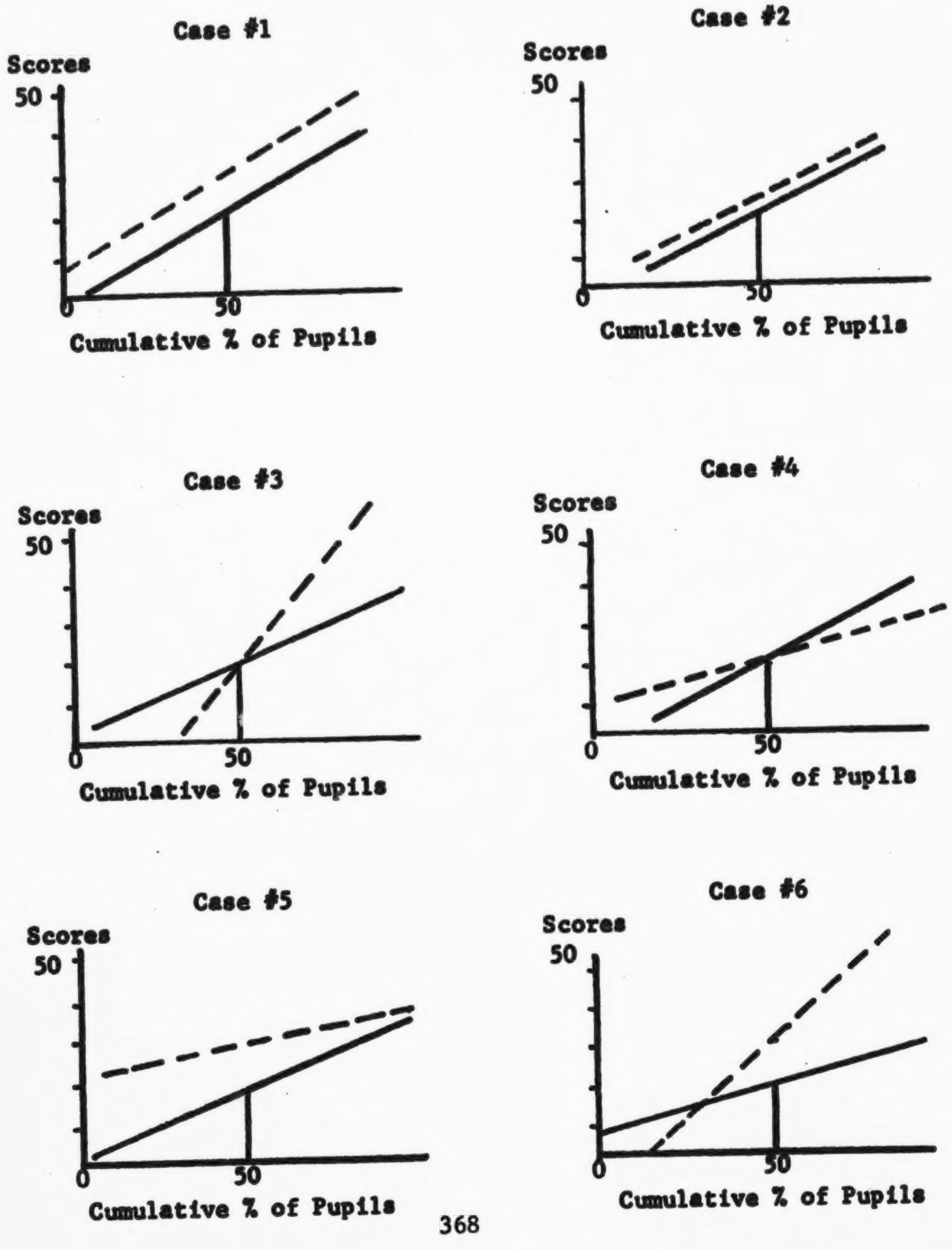
If the distribution of scores on the pre-test is skewed and the distribution of scores on the post-test is skewed, this is indicated by the expression (S-S). If the direction of skewness has not changed, this indicates that the distribution of scores within the class has not been altered by instruction. On the other hand, if there is a complete reversal of skewness in the distributions, this indicates a substantial alteration in the distribution of scores within the classroom.

C. Interpretation of Hypothetical Changes in Normal Distributions. Figure 23 identifies six hypothetical instances in which the comparison of graphs plotted before instruction with those plotted after instruction has enabled the researcher to detect notable changes in one or more classes of pupils. In hypothetical case #1, shown in Figure 23, the solid line indicates the pupils' achievement before instruction and the dash line indicates the pupils' success on the same test after instruction has concluded. It is apparent that there was an improvement in the class' scores after instruction. Arbitrarily, a change of two raw score points in the median scores or a change of 1.5 points in the rate of change (slope) was considered a significant change. Since the dash line is parallel to the solid line in case #1, this indicates that the improvement in the pupils' scores was uniform for pupils who scored low, average or high on the initial test.

In hypothetical case #2 of Figure 23, there were no significant gains for the pupils as a result of the instruction in the topic. This was consistent for pupils who were low, average, or high on the initial test.

In hypothetical case #3, there were no significant gains for the entire group. However, the sharp increase in the average rate of change for the graph of scores after instruction (dash line), without a corresponding significant change in the median scores, indicates that those pupils who made high scores on the initial test did make substantial growth as a result of instruction. Those pupils who were low on the initial test either made no improvement or made lower scores on the test after instruction.

Figure 23 HYPOTHETICAL CASES ILLUSTRATE CHANGES IN GRAPHS OF NORMAL DISTRIBUTION FOR CLASS SCORES PLOTTED FOR PRE-TESTS (M12,E12,H12) AND POST-TESTS (M23,E23,H23)



In the hypothetical case #4, there were no significant gains for the entire group. However, the dash line shows a sharp decrease in its slope when compared to the slope of the solid line. There was not a substantial increase or decrease in the mean score of pupils in this case. Therefore, it is apparent that the pupils who scored low on the initial test made considerable improvement as indicated by the dash line for the test after instruction, and pupils who scored high on the initial test, regressed to a lower level.

In hypothetical case #5, there was a significant improvement in the median score following instruction. However, the slope of the dash line has diminished sharply when it is compared to the slope of the solid line. This indicates that the pupils who scored low on the initial test made considerable growth in their understanding of the topics. However, the pupils who scored above the median on the initial test, did not made corresponding growth as indicated by the post-test scores.

In hypothetical case #6, there was a significant increase in the median score after instruction. Since the slope of the dotted line has also increased sharply, the average rate of improvement is substantially high for pupils who scored above the median on the initial test. The rate of improvement diminishes for pupils below the median to indicate small or insignificant improvement in their understanding as a result of the instruction.

Consideration of the graphs indicating median scores and the slopes of curves which indicated the average rate of change for pupils before and after instruction enabled the researcher to draw inferences about which segments of a particular class have made improvement in their understanding of the topics in the units. It should be apparent that many of these subtle interpretations would be obscured or lost, if the researcher had neglected to utilize the graphical methods as a supplement to the numerical methods.

Table 206 SUMMARY OF GRAPHICAL ANALYSIS OF FOURTH GRADE CLASSES FOR UNIT ACHIEVEMENT TESTS

| | | M12 | | | | M23 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Soc. Econ. | No. | Dist. | Md. | dY/dX | No. | Dist. | Md. | dY/dX | Interpretation* |
| 19 | Low | 13 | N | 5.5 | 2.5 | 11 | N | 8.5 | 5.5 | (N-N), Case 6 |
| 20 | Low | 22 | N | 6.0 | 2.5 | 12 | N | 5.5 | 4.0 | (N-N), Case 3 |
| 9 | Mid | 24 | N | 9.0 | 4.5 | 20 | N | 14.5 | 6.5 | (N-N), Case 6 |
| 10 | Mid | 19 | N | 6.0 | 2.5 | 20 | N | 8.5 | 5.0 | (N-N), Case 6 |
| 23 | Mid | 16 | LN | 6.5 | log.21 | 18 | N | 9.5 | 4.0 | (LN-N) |
| 24 | Mid | 19 | N | 7.5 | 4.0 | 20 | N | 12.0 | 4.5 | (N-N), Case 1 |
| 38 | High | 18 | N | 8.5 | 5.0 | 20 | N | 13.0 | 6.5 | (N-N), Case 6 |

Legend: No...Number of pupils used to plot graph
Dist...Distribution is normal (N), log normal (LN), skewed (S), log skewed (LS)
Md...Median score for class
dY/dX...Rate of change (standard deviation)

*Interpretation...Class 19 had normal distributions (N-N) on M12 and M23 tests. Since the median score increased on M23 test and the average rate of change increased (dY/dX), this is characteristic of hypothetical case #6 in Figure

Table 207 SUMMARY OF GRAPHICAL ANALYSIS OF FOURTH GRADE CLASSES FOR UNIT ACHIEVEMENT TESTS

| | | E12 | | | | E23 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Soc. Econ. | No. | Dist. | Md. | dY/dX | No. | Dist. | Md. | dY/dX | Interpretation |
| 19 | Low | 17 | N | 3.0 | 3.0 | 30 | N | 4.5 | 3.5 | (N-N), Case 2 |
| 20 | Low | 14 | LN | 2.5 | log.37 | 21 | N | 4.0 | 2.5 | (LN-N) |
| 9 | Mid | 18 | N | 7.5 | 5.0 | 24 | S+ | 9.0 | 5.5 | (N-S) |
| 10 | Mid | 18 | N | 5.0 | 3.5 | 23 | LN | 5.5 | log.32 | (N-LN) |
| 23 | Mid | 22 | N | 6.5 | 3.0 | 22 | N | 9.5 | 5.0 | (N-N), Case 6 |
| 24 | Mid | 26 | N | 5.0 | 3.5 | 25 | N | 8.5 | 5.0 | (N-N), Case 6 |
| 38 | High | 23 | N | 6.5 | 5.0 | 27 | N | 9.0 | 6.0 | (N-N), Case 1 |

Legend: No...Number of pupils used to plot graphs
Dist...Distribution is normal (N), log normal (LN), skewed (S), log skewed (LS)
Md...Median score for class
dY/dX...Rate of change (standard deviation)

Table 208 SUMMARY OF GRAPHICAL ANALYSIS OF FOURTH GRADE CLASSES FOR UNIT ACHIEVEMENT TESTS

| | | H12 | | | | H23 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Soc. Econ. | No. | Dist. | Md. | dY/dX | No. | Dist. | Md. | dY/dX | Interpretation |
| 19 | Low | 31 | S+ | 4.5 | 3.0 | 19 | S+ | 4.5 | 4.5 | (S-S) |
| 20 | Low | 25 | N | 7.0 | 4.5 | 13 | N | 5.5 | 4.0 | (N-N), Case 2 |
| 9 | Mid | 28 | N | 12.0 | 6.5 | 29 | N | 17.0 | 8.5 | (N-N), Case 6 |
| 10 | Mid | 22 | N | 8.5 | 7.0 | 21 | N | 12.0 | 8.0 | (N-N), Case 1 |
| 23 | Mid | 25 | LN | 10.0 | log.18 | 21 | LN | 11.0 | log.24 | (LN-LN) |
| 24 | Mid | 25 | N | 9.5 | 5.5 | 20 | N | 12.0 | 4.5 | (N-N), Case 1 |
| 38 | High | 38 | N | 10.0 | 5.5 | 16 | N | 12.5 | 7.0 | (N-N), Case 6 |

Legend: No...Number of pupils used to plot graphs
Dist...Distribution is normal (N), log normal (LN), skewed (S), log skewed (LS)
Md...Median score for class
dY/dX...Rate of change (standard deviation)

Table 209 SUMMARY OF GRAPHICAL ANALYSIS OF FIFTH GRADE CLASSES FOR UNIT ACHIEVEMENT TESTS

| | | M12 | | | | M23 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Soc. Econ. | No. | Dist. | Md. | dY/dX | No. | Dist. | Md. | dY/dX | Interpretation |
| 1 | Low | 29 | N | 7.0 | 3.0 | 9 | N | 7.5 | 3.0 | (N-N), Case 2 |
| 2 | Low | 26 | LN | 10.0 | log.15 | 27 | N | 12.0 | 7.0 | (LN-N) |
| 21 | Low | 34 | N | 6.5 | 3.0 | 13 | N | 9.0 | 4.5 | (N-N), Case 6 |
| 6 | Mid | 23 | N | 11.5 | 4.0 | 22 | LN | 15.0 | log.16 | (N-LN) |
| 11 | Mid | 28 | LN | 7.0 | log.33 | 25 | N | 13.0 | 5.0 | (LN-N) |
| 12 | Mid | 30 | N | 12.0 | 7.0 | 28 | N | 17.0 | 6.5 | (N-N), Case 1 |
| 15 | Mid | 23 | N | 10.0 | 4.0 | 15 | N | 15.0 | 8.0 | (N-N), Case 6 |
| 16 | Mid | 24 | LN | 7.5 | log.24 | 21 | N | 9.5 | 5.5 | (LN-N) |
| 25 | Mid | 15 | N | 11.5 | 5.0 | 15 | LN | 15.0 | log.13 | (N-LN) |
| 26 | Mid | 19 | N | 8.0 | 5.0 | 19 | LN | 13.0 | log.19 | (N-LN) |
| 32 | High | 27 | N | 11.0 | 7.5 | 29 | S+ | 18.5 | 11.5 | (N-S) |
| 33 | High | 30 | N | 8.0 | 4.0 | 27 | N | 14.0 | 6.5 | (N-N), Case 6 |
| 34 | High | 21 | N | 10.0 | 3.5 | 21 | S+ | 12.5 | 4.5 | (N-S) |
| 39 | High | 21 | N | 8.5 | 5.0 | 24 | N | 15.5 | 8.0 | (N-N), Case 6 |

Legend: No...Number of pupils used to plot graphs
Dist...Distribution is normal (N), log normal (LN), skewed (S), log skewed (LS)
Md...Median score for class
dY/dX...Rate of change (standard deviation)

Table 210 SUMMARY OF GRAPHICAL ANALYSIS OF FIFTH GRADE CLASSES FOR UNIT ACHIEVEMENT TESTS

| | | E12 | | | | E23 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Soc. Econ. | No. | Dist. | Md. | dY/dX | No. | Dist. | Md. | dY/dX | Interpretation |
| 2 | Low | 24 | N | 6.0 | 5.0 | 23 | LN | 7.0 | log.30 | (N-LN) |
| 21 | Low | - | - | - | - | 29 | LN | 6.0 | log.25 | - |
| 6 | Mid | 24 | N | 9.0 | 4.5 | 24 | S+ | 12.0 | 6.0 | (N-S) |
| 11 | Mid | 20 | N | 8.5 | 3.0 | 20 | LN | 11.5 | log.19 | (N-LN) |
| 12 | Mid | 26 | S+ | 7.5 | 5.0 | 25 | N | 14.0 | 8.5 | (S-N) |
| 15 | Mid | 14 | N | 10.0 | 6.5 | 21 | N | 14.0 | 9.5 | (N-N), Case 6 |
| 16 | Mid | 25 | N | 6.5 | 4.5 | 20 | LS+ | 8.0 | log.26 | (N-LS) |
| 25 | Mid | 25 | N | 9.0 | 4.5 | 18 | LN | 7.5 | log.39 | (N-LN) |
| 26 | Mid | 22 | S+ | 7.0 | 4.5 | 23 | LN | 9.0 | log.33 | (S-LN) |
| 55 | Mid | - | - | - | - | 13 | N | 10.5 | 4.5 | - |
| 32 | High | 26 | N | 9.0 | 4.5 | 26 | S+ | 12.0 | 7.0 | (N-S) |
| 33 | High | 19 | S+ | 6.0 | 3.5 | 25 | S+ | 10.0 | 5.5 | (S-S) |
| 34 | High | 21 | S+ | 6.0 | 3.5 | 22 | LN | 9.5 | log.29 | (S-LN) |
| 39 | High | 22 | N | 6.0 | 4.0 | 25 | LN | 7.5 | log.23 | (N-LN) |

Legend: No...Number of pupils used to plot graphs
Dist...Distribution is normal (N), log normal (LN), skewed (S), log skewed (LS)
Md...Median score for class
dY/dX...Rate of change (standard deviation)

Table 211 SUMMARY OF GRAPHICAL ANALYSIS OF FIFTH GRADE CLASSES FOR UNIT ACHIEVEMENT TESTS

| | | H12 | | | | H23 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Soc. Econ. | No. | Dist. | Md. | dY/dX | No. | Dist. | Md. | dY/dX | Interpretation |
| 2 | Low | 27 | LN | 9.0 | log.25 | 22 | S+ | 11.0 | 7.0 | (LN-S) |
| 21 | Low | 35 | LN | 9.0 | log.25 | 24 | S+ | 10.0 | 5.0 | (LN-S) |
| 6 | Mid | 21 | N | 12.0 | 4.5 | 19 | N | 17.0 | 6.0 | (N-N), Case 6 |
| 11 | Mid | 24 | N | 12.5 | 5.5 | 22 | N | 15.0 | 7.5 | (N-N), Case 6 |
| 12 | Mid | 26 | N | 15.0 | 5.0 | - | - | - | - | - |
| 15 | Mid | 24 | N | 13.0 | 5.0 | 23 | N | 15.5 | 5.5 | (N-N), Case 1 |
| 16 | Mid | 28 | N | 9.5 | 5.5 | 28 | N | 12.0 | 6.0 | (N-N), Case 1 |
| 25 | Mid | 20 | LN | 12.0 | log.18 | 21 | S+ | 13.5 | 8.0 | (LN-S) |
| 26 | Mid | 20 | N | 14.0 | 7.5 | 18 | N | 18.0 | 8.5 | (N-N), Case 1 |
| 32 | High | 29 | N | 14.0 | 6.5 | 31 | S+ | 18.0 | 7.0 | (N-S) |
| 33 | High | 33 | N | 13.0 | 5.0 | 33 | N | 16.0 | 7.5 | (N-N), Case 6 |
| 34 | High | 25 | N | 13.0 | 6.0 | 24 | N | 14.5 | 7.5 | (N-N), Case 3 |
| 39 | High | 27 | N | 12.0 | 7.0 | 20 | N | 16.0 | 10.0 | (N-N), Case 6 |

Legend: No...Number of pupils used to plot graphs
Dist...Distribution is normal (N), log normal (LN), skewed (S), log skewed (LS)
Md...Median score for class
dY/dX... Rate of change (standard deviation)

Table 212 SUMMARY OF GRAPHICAL ANALYSIS OF SIXTH GRADE CLASSES FOR UNIT ACHIEVEMENT TESTS

| | | M12 | | | | M23 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Soc. Econ. | No. | Dist. | Md. | dY/dX | No. | Dist. | Md. | dY/dX | Interpretation |
| 3 | Low | 20 | LN | 9.0 | log.18 | 20 | N | 9.5 | 4.5 | (LN-N) |
| 4 | Low | 18 | N | 10.5 | 2.5 | 19 | N | 9.5 | 5.5 | (N-N), Case 3 |
| 22 | Low | 24 | LN | 8.5 | log.20 | - | - | - | - | - |
| 7 | Mid | 35 | N | 12.5 | 4.5 | 35 | N | 17.0 | 6.0 | (N-N), Case 6 |
| 8 | Mid | 33 | LN | 13.5 | log.17 | 33 | N | 18.0 | 6.5 | (LN-N) |
| 13 | Mid | 26 | N | 11.0 | 5.0 | 27 | N | 16.0 | 7.5 | (N-N), Case 6 |
| 14 | Mid | 33 | N | 12.0 | 4.0 | 26 | N | 16.0 | 5.5 | (N-N), Case 6 |
| 17 | Mid | 16 | N | 9.5 | 5.5 | 16 | N | 13.0 | 11.5 | (N-N), Case 6 |
| 18 | Mid | 27 | N | 12.0 | 6.0 | 17 | N | 13.0 | 7.0 | (N-N), Case 2 |
| 27 | Mid | 23 | N | 11.5 | 4.5 | 24 | N | 16.5 | 6.5 | (N-N), Case 6 |
| 28 | Mid | 34 | N | 14.0 | 5.5 | 20 | N | 16.5 | 5.0 | (N-N), Case 1 |
| 58 | Mid | 17 | N | 14.0 | 5.5 | 16 | N | 21.0 | 6.0 | (N-N), Case 1 |
| 88 | Mid | 22 | S+ | 12.0 | 8.0 | 19 | LS+ | 14.0 | log.23 | (S-LS) |
| 35 | High | 23 | N | 12.0 | 5.5 | 26 | N | 18.0 | 11.0 | (N-N), Case 6 |
| 36 | High | 23 | N | 11.0 | 5.5 | 23 | N | 17.0 | 7.0 | (N-N), Case 6 |
| 37 | High | 27 | N | 12.0 | 5.5 | 27 | N | 16.0 | 8.5 | (N-N), Case 6 |
| 40 | High | 25 | N | 13.5 | 6.5 | 27 | N | 18.0 | 9.0 | (N-N), Case 6 |
| 41 | High | 22 | N | 12.0 | 5.0 | 26 | N | 14.5 | 10.5 | (N-N), Case 6 |

Legend: No...Number of pupils used to plot graphs
Dist...Distribution is normal (N), log normal (LN), skewed (S), log skewed (LS)
Md...Median score for class
dY/dX...Rate of change (standard deviation)

Table 213 SUMMARY OF GRAPHICAL ANALYSIS OF SIXTH GRADE CLASSES FOR UNIT ACHIEVEMENT TESTS

| | | E12 | | | | E23 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Soc. Econ. | No. | Dist. | Md. | dY/dX | No. | Dist. | Md. | dY/dX | Interpretation |
| 3 | Low | 12 | N | 6.5 | 3.0 | 16 | S+ | 4.0 | 3.0 | (N-S) |
| 4 | Low | 23 | N | 6.0 | 4.0 | 19 | N | 7.5 | 4.5 | (N-N), Case 2 |
| 22 | Low | - | - | - | - | 26 | N | 5.0 | 3.0 | - |
| 7 | Mid | 30 | N | 5.0 | 5.5 | 35 | S+ | 12.0 | 7.0 | (N-S) |
| 8 | Mid | 34 | N | 8.0 | 5.0 | 33 | N | 13.0 | 5.5 | (N-N), Case 1 |
| 13 | Mid | 26 | LN | log.28 | 7.5 | 24 | S+ | 12.5 | 6.5 | (LN-S) |
| 14 | Mid | 24 | N | 9.5 | 6.0 | 26 | S+ | 14.0 | 4.0 | (N-S) |
| 17 | Mid | 12 | N | 5.5 | 6.0 | 14 | LN | 9.0 | log.39 | (N-LN) |
| 18 | Mid | 15 | LN | log.22 | 4.5 | 20 | N | 13.5 | 6.5 | (LN-N) |
| 27 | Mid | 21 | N | 8.0 | 5.0 | 21 | S+ | 14.0 | 6.0 | (N-S) |
| 28 | Mid | 22 | N | 9.0 | 4.5 | 23 | N | 13.0 | 6.0 | (N-N), Case 6 |
| 58 | Mid | 14 | N | 15.0 | 7.0 | 28 | N | 14.5 | 8.5 | (N-N), Case 3 |
| 35 | High | 16 | N | 11.5 | 4.5 | 19 | N | 17.5 | 9.5 | (N-N), Case 6 |
| 36 | High | 19 | LS+ | 9.5 | log.13 | 22 | N | 13.5 | 7.5 | (LS-N) |
| 37 | High | 18 | N | 10.5 | 6.0 | 20 | N | 17.0 | 10.5 | (N-N), Case 6 |
| 40 | High | 27 | N | 11.5 | 5.5 | 27 | N | 13.5 | 7.5 | (N-N), Case 6 |
| 41 | High | 25 | S+ | 6.0 | 4.0 | 30 | N | 8.5 | 7.5 | (S-N) |

Legend: No...Number of pupils used to plot graphs
Dist...Distribution is normal (N), log normal (LN), skewed (S), log skewed (LS)
Md...Median score for class
dY/dX...Rate of change (standard deviation)

Table 214 SUMMARY OF GRAPHICAL ANALYSIS OF SIXTH GRADE CLASSES FOR UNIT ACHIEVEMENT TESTS

| | | H12 | | | | H23 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Soc. Econ. | No. | Dist. | Md. | dY/dX | No. | Dist. | Md. | dY/dX | Interpretation |
| 3 | Low | 23 | LN | 6.0 | log.29 | - | - | - | - | - |
| 4 | Low | 25 | N | 7.0 | 5.0 | - | - | - | - | - |
| 7 | Mid | 38 | N | 11.0 | 6.5 | 34 | N | 18.0 | 8.5 | (N-N), Case 6 |
| 8 | Mid | 34 | N | 15.0 | 5.5 | 31 | N | 18.0 | 6.0 | (N-N), Case 1 |
| 13 | Mid | 28 | N | 17.5 | 7.0 | 25 | N | 19.5 | 9.0 | (N-N), Case 6 |
| 14 | Mid | 29 | N | 15.0 | 6.5 | 24 | N | 17.5 | 7.0 | (N-N), Case 1 |
| 17 | Mid | 27 | LS+ | 10.0 | log.25 | 28 | N | 13.0 | 7.5 | (LS-N) |
| 18 | Mid | 24 | N | 11.5 | 5.5 | 26 | N | 16.0 | 5.5 | (N-N), Case 1 |
| 27 | Mid | 22 | LS+ | 12.0 | log.26 | 21 | N | 19.0 | 7.0 | (LS-N) |
| 28 | Mid | 26 | N | 13.0 | 5.0 | 22 | N | 17.0 | 6.0 | (N-N), Case 1 |
| 58 | Mid | 31 | N | 16.5 | 7.0 | 26 | N | 19.5 | 9.5 | (N-N), Case 6 |
| 35 | High | 24 | LN | 15.0 | log.20 | 23 | N | 20.0 | 7.0 | (LN-N) |
| 36 | High | 26 | N | 15.0 | 6.0 | 22 | N | 17.0 | 6.0 | (N-N), Case 1 |
| 37 | High | 24 | N | 16.0 | 7.0 | 21 | N | 19.0 | 8.0 | (N-N), Case 1 |
| 40 | High | 29 | N | 17.0 | 8.0 | 27 | N | 21.0 | 9.0 | (N-N), Case 1 |
| 41 | High | 27 | N | 11.0 | 7.5 | 28 | N | 16.5 | 9.5 | (N-N), Case 6 |

Legend: No...Number of pupils used to plot graphs
Dist...Distribution is normal (N), log normal (LN), skewed (S), log skewed (LS)
Md...Median score for class
dY/dX...Rate of change (standard deviation)

## I-1

# UNIT PLAN OF INSTRUCTION ON TOPIC OF SIMPLE MACHINES

BY:

Gary R. Smith
Associate Professor
College of Education
Wayne State University
Cooperative Research Project 2409

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## I-2

## SUGGESTIONS FOR TEACHING UNIT

1. Begin each day with a question, illustration, or activity which will capture the interests of the pupils. Whenever possible utilize questions or objects brought to class by your pupils.
2. Elicit possible explanations or answers from several pupils. Don't tell answers immediately. Ask a child to explain, illustrate or give reasons for accepting a particular answer.
3. Guided by your judgement and the teaching circumstances, give as many pupils as possible an opportunity to do the activities.
4. Use the science textbooks to expand their understanding of the ideas introduced in class. The appropriate text material is to be read silently and then aloud.
5. The concepts presented in Column #1 are intended for the teacher's guidance. They are not to be copied by the children as something to memorize. It is hoped that the pupils will begin to make similar generalizations as a result of the activities, the class discussions and their reading. Encourage your pupils to generalize; but also urge them to use the vocabulary and expressions which are meaningful to them.
6. If circumstances permit, place apparatus in a science corner where children may repeat the activities during their free time.
7. The chalkboard illustrations may be sketched on large newsprint or at the board.
8. Don't try to make your pupils "Machine Experts." Help them to conclude their study with a feeling that they've learned a great deal about machines. They'be learned the explanations for many things which they previously had taken for granted. However, there are still many things which they don't know about simple machines. Help them to close the unit with an interest in continuing the study of machines "on their own."

## FIRST DAY -- GENERALIZATIONS

1. Energy is the ability to do work.
2. Mechanical energy is energy produced by a machine.
3. The energy used to do work is not lost or destroyed but its form may be changed.
4. Work is done when a force moves an object.
5. A force is a push or pull in some direction.

## CLASS ACTIVITIES

**Reading**: Read pages 3-7 silently and then aloud (if time permits).

**New Words**: energy, mechanical, work force

**Materials**: 2 rods, 10'rope

**Pupil Questions**:

1. Can I see energy?
2. Where is energy?
3. How many different kinds of energy are there?
4. When is someone doing work?
5. Why could you pull the rods together with the rope?

## CHALKBOARD ILLUSTRATIONS

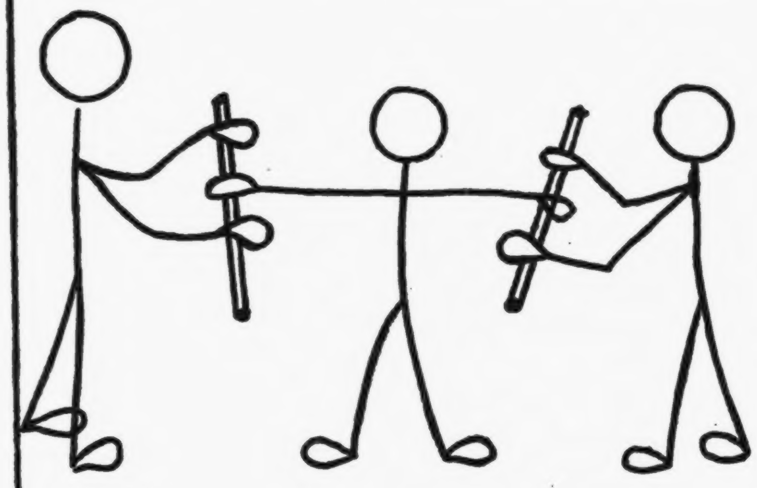

Fig. 1
Pupil tries to pull rods together

**Discussion**: Discuss with the pupils their understandings of the words: energy, force, work. Accept their ideas but caution them that the scientist has a special meaning for each of these words. Help pupils understand the scientist's meaning for these words. Make a list on chalkboard of examples of sources of energy (people, foods, electricity, sunlight....), work (talking, walking, breathing, and moving object), force (wind, baseball batter, weight of person).

***Activities**: Have two boys come to front of room. Teacher and one boy hold the two rods. Second boy stands between the teacher and other boy. Second boy tries to pull rods together while teacher and first boy try to keep rods separated (as shown in figure 1). Next, tie rope onto one rod and wrap it around rods (as shown in figure 2). Have second boy stand behind teacher and pull on rope. Teacher and first pupil will not be able to keep the rods apart. Invite pupils to explain why the same person could pull the rods together with the rope, but not without it. Repeat with another group if time permits. In the discussion and at the chalkboard, call attention to the existing forces, sources of energy, work done.

**Results Expected**: Using the rope (as shown in Figure 2) will make a form of pulley system. This simple machine has increased the magnitude of his force about four times. Don't bother to identify this simple machine at this time. Tell the pupils that they'll meet this simple machine later and you want to discover if they will recognize it.

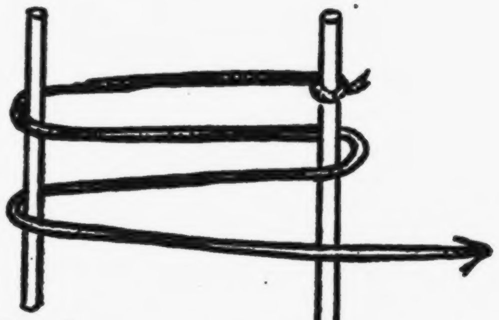

Fig. 2
Rope attached to rods

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## I-4

## SECOND DAY -- GENERALIZATIONS

1. A machine makes it easier to do work.
2. A lever is one kind of simple machine.
3. In a first-class lever the fulcrum is between the load and the effort force.
4. In a second-class lever, the load is always between the effort force and the fulcrum.
5. In a third-class lever, the load is always between the fulcrum and the force.

## CLASS ACTIVITIES

**Reading**: Read pages 10-12 silently and aloud.

**New Words**: lever, fulcrum, effort force, load

**Materials**: 9-foot plank, 4 books

**Pupils Questions**:

1. What is a lever?
2. Where do we use levers?
3. Why do we need machines?
4. Where is the fulcrum?
5. How are the fishing poles being used?
6. How can you remember the difference between 1st, 2nd, 3rd class levers?

## CHALKBOARD ILLUSTRATIONS

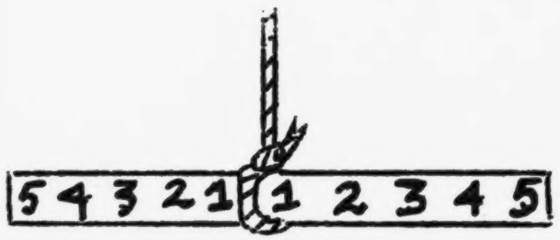


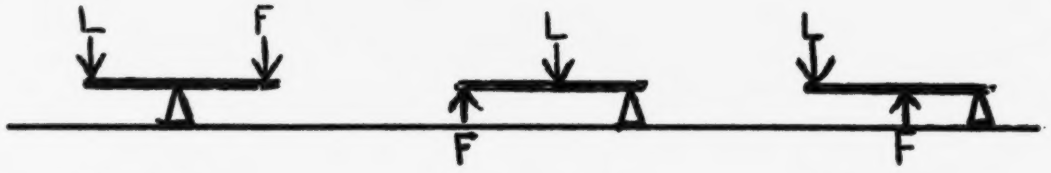
Fig. 1 Plank arranged as Lever

**Discussion**: Ask pupils to read pages 10-12 and attempt to answer some of the questions listed above. During the discussion ask them to interpret the pictures which accompany the reading. List on the chalkboard the different kinds of levers which they will find at school or in their home (pencils, scissors, teeter totter, pliers, broom, wheelbarrow, shovel). Ask pupils to bring examples of levers to class. Call attention to combinations of two levers in scissors, tweezers, pliers. If possible, have examples of these simple machines brought to class. Use the word "FU-L-F" as a mnemonic device to help pupils remember the three classes of levers: FUlcrum in middle (1st class)...Load in middle (2nd class)...Force in middle (3rd class).

***Activities**: Use plank to form a lever with the fulcrum in the middle (as shown in figure 1). Two books tied together with string can be used as the "load" or as the "lifting force." Try different weights of books as the load. Ask one or more pupils to come to the front of the room to form a second-class lever and a third-class lever. Reinforce these concepts with illustrations at the chalkboard.

**Results Expected**: The list of first-class levers will include: hammer, scissors, teeter totter, crowbar. The list of second-class levers will include: wheelbarrow, bottle opener, nutcracker. The list of third-class levers will include: fishing pole, broom.

The fishing poles on page 13 of the text are used differently. The boy is using a first-class lever since his toe is the load and the stick is the fulcrum. The girl is using the fishing pole in the customary way (third-class lever).



First Class Second class Third Class

Fig. 2 Three Classes of Lever

I-5

## THIRD DAY --GENERALIZATIONS

1. The load arm is the distance between the fulcrum and the load.
2. The force arm is the distance between the fulcrum and the effort force.
3. Pliers, bottle openers, brooms, baseball bats, and shovels are examples of the lever.
4. When the force arm is longer than the load arm, a small force moves a heavy load.
5. When the force arm is as long as the load arm, no mechanical advantage is gained.

## CLASS ACTIVITIES (REVISED)

**Reading:** Read pages 13-15 silently and aloud.

**New Words:** load arm, force arm

**Materials:** hand scale, plank, chair, weights, levers for pupils, washers

**Pupil Questions:**

1. What's the difference between the load arm and the force arm?
2. What is meant by "trading force for distance?"

## CHALKBOARD ILLUSTRATIONS

| LOAD | LOAD ARM | FORCE | FORCE ARM |
|---|---|---|---|
| 4# | 2' | ? | 4' |
| 6# | 1' | 3# | ? |

Fig. 1 Table of Load-Force Relationships for Lever

**Discussion:** Briefly review pupils' understanding of the three classes of lever (FULF). Clarify the meaning of the terms "load arm" and "force arm." Use illustrations at the chalkboard.

Discuss the illustrations on pages 14 and 15 of the text. Note size of load arm and force arm. If the elephant weighed about 100 times more than the boy, the boy would have to be about 100 times as far from the fulcrum as the elephant in order for them to balance evenly.

***Activities:** Use the 10-foot plank to review briefly the three classes of lever. In each instance, have the pupils identify the fulcrum, load, and lifting force.

Balance the plank to form a 1st class lever. Use two or more books tied together as the load. Place a 4# load approximately 2' from the fulcrum. Have a pupil use the hand spring balance to raise the load when the force arm is 4' (See Fig. 1). Ask pupils to estimate the amount of force before the pupil actually lifts the load with the hand spring balance. Repeat the activity with a 4# load and a 4# force (another pack of books) to illustrate that the equal forces will balance when they are at equal distances from the fulcrum. Take the pupil lever (Fig 2) and twist it so that the red-green lever moves freely around the nail. Ask pupils to identify the fulcrum. Arbitrarily identify red as the load and green as the lifting force. Show pupils how different combinations of washers on the red side can be balanced by other combinations on the green side. Have one or more pupils do this for their classmates.

**Results Expected:** With three washers at two units from the fulcrum, only two washers will be needed at three units from the fulcrum. When the red load arm is one unit and the load is three washers, a lifting force of one washer at 3 units from the fulcrum will balance the load.

Use the chart in Fig. 1 to reinforce their understandings. Some pupils will be able to generalize that:

(load) x (load arm) = (force) x (force arm)

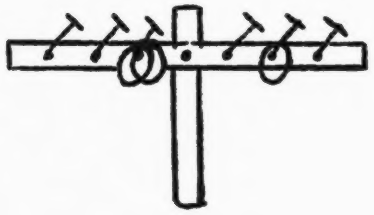


Fig. 2 Pupils' Lever

## I-6

## FOURTH DAY -- GENERALIZATIONS

1. When the force arm is longer than the load arm, the effort force is moved a greater distance than the load.
2. When the load arm is longer than the force arm, the load travels farther than the force.
3. When the load arm is longer than the force arm, the load travels faster than the force.
4. When the load arm is longer than the force arm, the force must be greater than the load in order to move it.

## CLASS ACTIVITIES

**Reading**: Complete reading pages 13-15

**New Words**: Speed

**Materials**: baseball bat, broom, hand spring balance, plank, books for weight.

**Pupil Questions**:

1. When do we want the load arm to move very fast?
2. How is a broom like a lever?
3. How is a pulley or wheel and axle like a lever?

## CHALKBOARD ILLUSTRATIONS

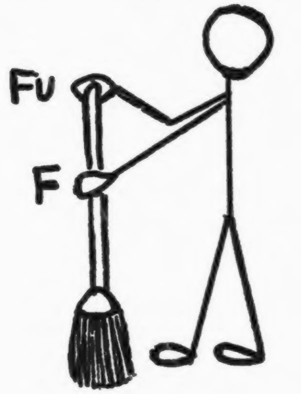


Fig. 1 Broom as Third Class Lever

Discussion: Ask pupils if they can think of an occasion when it might be very important to move the load arm very rapidly. Suggest that this is necessary when batting a baseball or hitting a hockey puck or sweeping with a broom.

*Activities: Teacher or pupil may demonstrate use of broom (as shown in Figure 1). Call attention to the distance the load is moved and the distance the force moves. Tie a string to a yard stick and use it as a fishing pole. Encourage pupils to generalize that the load arm is longer than the force arm in the third-class levers. They should also be able to see that when a third-class lever is used, the load will travel farther than the force. Have a boy come to the front of the room to demonstrate the swing of a batter. Call attention to the load distance and to the force distance.

Ask pupils if more force or less force will be needed to move a load with a third-class lever. Encourage them to explain their reasons. Use the plank as a lever to check the pupils' estimates.

Results Expected: In each instance call attention to the small distance moved by the force as compared to the large distance moved by the load. Sweeping with a broom or lifting a load with a shovel are clear instances of the third-class lever. Hitting a baseball is complicated motion, but essentially a third-class lever is used.

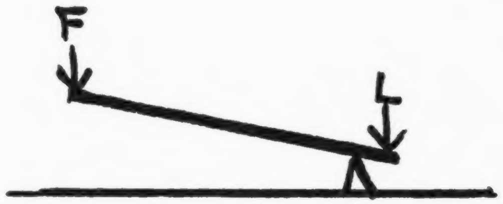


Fig. 2 First Class Lever

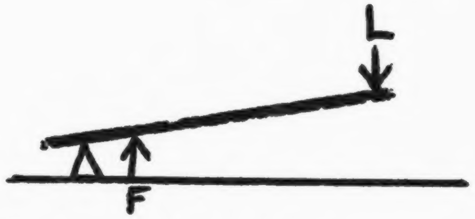


Fig. 3 Third Class Lever

## FIFTH DAY - SHOW FILMSTRIP #3, "LEVERS AT WORK" (JAM HANDY, DETROIT, MICH.) - READ CAPTIONS ALOUD IN CLASS

THIS PAGE INCLUDED THE EXACT TEXT USED IN THE CAPTIONS OF THE FILMSTRIP. USING THIS TEXT, THE TEACHER COULD PREVIEW MAIN IDEAS TO EMPHASIZE IN THE FILMSTRIP. THE TEXT IS NOT INCLUDED HERE IN ORDER TO AVOID INFRINGEMENT OF JAM HANDY COPYRIGHT.

## SIXTH DAY -- GENERALIZATIONS

1. The pulley and the wheel and axle are special kinds of levers.

2. A single fixed pulley needs a force larger than the load to be lifted.

3. A movable pulley and a small force can be used to lift a heavier load.

4. A single fixed pulley is used to move a load by pulling in the opposite direction.

5. Elevators, hoists, steam shovels and the painters' **scaffolds** use pulleys.

## CLASS ACTIVITIES

Reading: Read pages 16-17 silently and aloud.

New Words: pulley, strands, movable pulley, single-fixed pulley

Materials: rope, weights, single and double pulleys, pole

Pupil Questions:

1. If a lever is like a pulley where is the fulcrum on the pulley?
2. Where are pulleys used?
3. What is a 2-strand pulley?
4. What is a 3-strand pulley?
5. In Figure 2, where is the force arm?

Discussion: Utilize pictures of pulley in book or at chalkboard to identify similarities between lever and pulley (Figures 1,2). Ask pupils to read pages 16-17 and try to answer questions 1,2,3,4, (above). In Figure 2, the solid line is the "load arm" and the dotted line is the "force arm."

Activities: Hang a pulley from an overhead support (Figure 2). Use a single pulley (Figure 2) to lift a 4# load of books. Have one of the pupils use a hand spring balance to measure the force needed to lift the load. Attach a movable pulley (Figure 3) to the 4# load and measure the lifting force needed this time. Urge pupils to identify the number of strands coming from the load. Repeat the same activity using weights of 6# and 8#.

Results Expected: A pulley is similar to a first-class lever having equal distances for load arm and force arm. This is illustrated in Figures 1 and 2.

A force greater than the load will be required when a single-strand pulley is used to move a load. The extra force is needed to overcome friction. With a 2-strand pulley 30# can be lifted by a 15# force. With a 3-strand pulley, 30# can be lifted by a 10# force.

## CHALKBOARD ILLUSTRATIONS

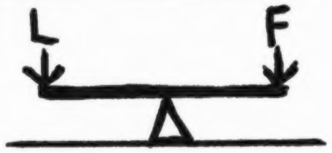


Fig 1 First Class Lever

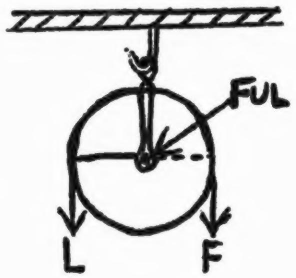


Fig. 2 Load, Force, Fulcrum of Fixed Pulley

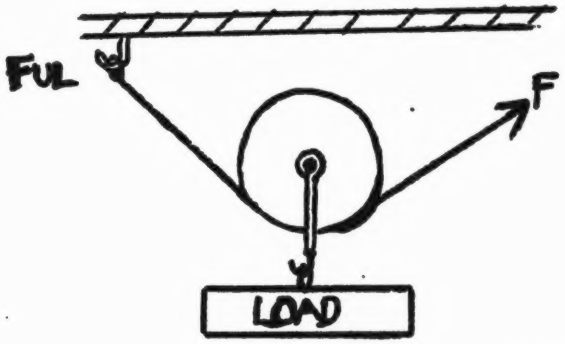


Fig. 3 Load, Force, Fulcrum of Movable Pulley

## SEVENTH DAY -- GENERALIZATIONS

1. A load is raised a short distance by a movable pulley, but the lifting force must travel a long distance.
2. Pulleys can be combined to lift very heavy loads.
3. The number of strands in a pulley system indicates the gain in lifting force.

## CLASS ACTIVITIES

Reading: Read pages 18-19 silently and aloud.

New Words: pulley system, hoist, elevator, painters' scaffold

Materials: pulleys, pole, rope, hand scales, weights

Pupil Questions:

1. How many strands in the pulleys in Figures 1 and 4?

## CHALKBOARD ILLUSTRATIONS

| STRANDS | LOAD | FORCE |
|---|---|---|
| 2 | 6# | ? |
| 3 | 6# | ? |

Fig. 2 Table of Load-Force Relationships for Pulleys

Discussion: After pupils have read pages 18-19 in text, ask someone to interpret the table on page 17 of the text. Encourage pupils to note the relation between number of strands and effort force. Pupils should recognize the relation between number of strands and the ratio of force distance to load distance.

*Activities: Arrange a load of 8# with a movable pulley as shown in Figure 1. After pupils have estimated the force needed to lift this load, have one pupil read the hand scale as the load is lifted with the pulley. Repeat the activity and measure the distance the force must move when the load is raised about one foot. Repeat the activity with a 3-strand or 4-strand pulley system. Record the data in a table as shown in Figure 2.

Results Expected: Pupils will state that the lifting force is found by dividing the load by the number of strands in the pulley system. That is, a 5-strand pulley can be used to lift a 60# load with only 12# of force (60# ÷ 5).

Help the pupils to generalize that the number of strands in the pulley system indicated the distance the force must move for each unit of distance moved by the load. For example, a five-strand pulley requires a force to move five feet for every single foot that the load is raised.

Repeat the activity used on the first day of the unit with the two rods and the rope. Pupils should note that this simple machine was a form of pulley system.

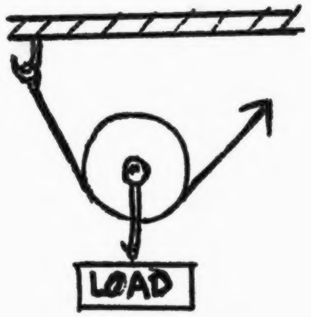


Fig. 1
Two-Strand
Movable Pulley

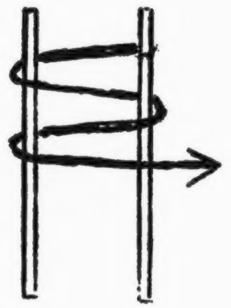


Fig. 3
Pulley System
Using two Rods

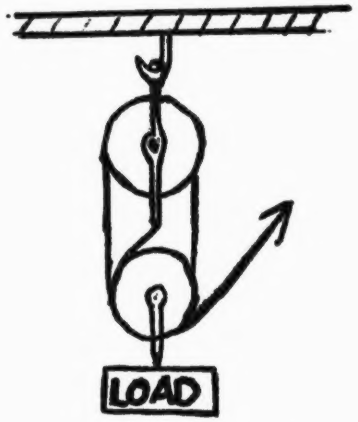


Fig. 4
Four-Strand
Pulley

## EIGHTH AND NINTH DAYS -- GENERALIZATIONS

1. When a wheel and axle is turned, a point on the rim of the wheel travels farther than does a point on the rim of the axle.

2. When a wheel and axle is turned, the edge of the wheel travels faster than the edge of the axle.

3. A small force on the wheel will move a heavy load on the axle.

4. As the wheel becomes larger, it takes less force on the wheel to move the same load on the axle.

t. The wheel and axle is often used in automobiles, bicycles, and home appliances.

## CLASS ACTIVITIES

Reading: Read pages 20-21 silently and aloud

New Words: wheel and axle, rim

Materials: 2 rods, twine, wrenches, bicycle, nuts and bolts, screwdriver

Pupil Questions:

1. Where do we use the wheel and axle?
2. How is a wheel and axle like a lever?
3. On p. 20, which wheel needs the least effort? In which does the force travel farthest?
4. On p. 21, what is gained when the force is applied to the small wheel? Where would you use this?

## CHALKBOARD ILLUSTRATIONS

Fig. 1
Rods Used
as Wheel
and Axle

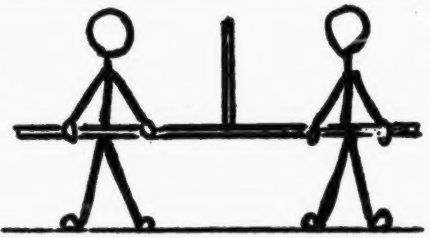
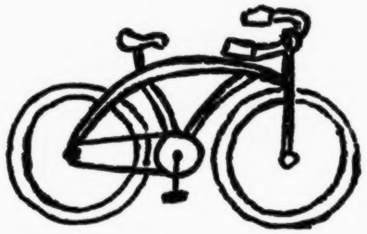


Fig. 2
Bicycle Uses
Many Wheel
and Axle
Combinations



Discussion: Encourage pupils to suggest several common uses of the wheel and axle. List these on the chalkboard and/or illustrate with actual examples in the classroom. Discuss the two pictures on pages 20.21. In what kind of a machine would you wish to gain speed? Help pupils to recognize that if the force moves in a circular path, it is not necessary for the entire wheel to be used.

*Activities: Have two boys hold a rod and then attach a second rod to it as shown in Figure 1. Ask a girl to come to the front and turn the second rod. The boys will not be strong enough to prevent the pole from turning in their hands. Suggest to pupils that this is another example of very powerful simple machine.

After the pupils have read the text and can identify the basic parts of the wheel and axle, have one or more pupils attempt to open the classroom door without the doorknob. Have another child attempt to sharpen a pencil by turning only the rod on the pencil sharpener. Have two or more children attempt to loosen nuts on bolts with their fingers and then with a wrench. In each instance encourage pupils to identify the path of the wheel and axle.

Have a pupil bring into class his bicycle. Encourage pupils to identify the different instances of the wheel and axle.

Results Expected: In the first activity, the girl is using a long force arm. This exerts a tremendous force on the rod held by the two boys. The doorknob, pencil sharpener and wrenches are also instances of a gain in force by using a wheel and axle. Other examples include most wheels on bicycles and autos, fans, telephone dials, egg beaters, augers and drills, faucet handles, ferris wheel. As the text explains, the wheel and axle makes it possible to gain force or speed. The wheel and axle in diagram B on page 20 will require less effort to lift the same load as the machine in diagram A on page 21. Wheel D would travel faster that wheel C, but it would also require more force to do this.

The bicycle pedal exerts a small force on a large force arm. This is transferred by the chain to a small wheel and axle which increases the speed of the very large rear wheel. When the handle bars are turned, this is also a wheel and axle machine.

TENTH DAY - SHOW FILMSTRIP #5, "WHEELS AND AXLES AT WORK" (JAM HANDY, DETROIT, MICH.) - HAVE CAPTIONS READ ALOUD IN CLASS

THIS PAGE INCLUDED THE EXACT TEXT USED IN THE CAPTIONS OF THE FILMSTRIP. USING THIS TEXT, THE TEACHER COULD PREVIEW MAIN IDEAS TO EMPHASIZE IN THE FILMSTRIP. THE TEXT IS NOT INCLUDED HERE IN ORDER TO AVOID INFRINGEMENT OF JAM HANDY COPYRIGHT.

## ELEVENTH AND TWELFTH DAY -- GENERALIZATIONS

1. An inclined plane is another kind of simple machine.

2. An inclined plane raises a heavy load a short distance by moving a small force through a long distance.

3. Wedges and screws are special forms of the inclined plane.

4. Many machines are made by using two or more simple machines together.

## CLASS ACTIVITIES

__Reading__: Read pp. 8-9, 22-25, 26-28, Use Filmstrip on Inclined Plane.

__New Words__: inclined plane, screw, thread, wedge

__Materials__: board, skates, rope, hand balance, paper triangles, screws.

__Pupil Questions__:

1. How does an inclined plane make work easier?
2. Where is the inclined plane on a screw or wedge?
3. How does a screw gain force?
4. How does a wedge gain force?
5. Where are screws and wedges used?

## CHALKBOARD ILLUSTRATIONS

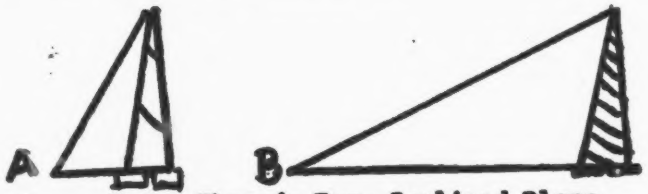


Fig. 2 Screw Threads Form Inclined Plane

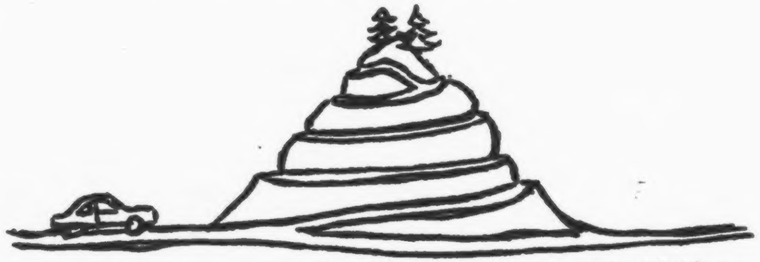


Fig. 3 Road Up Mountain is Inclined Plane

__Discussion__: Pupils should be able to identify the two inclined planes in a wedge. The screw will be recognized as an extended inclined plane. Those questions encountered in the text should be answered briefly. After reading the text silently, encourage pupils to identify familiar examples of the screw, wedge or inclined plane. If possible, have examples of these on hand.

A discussion can be developed by setting a hypothetical scene in a home, and have the pupils build a story of events where they use different inclined planes (going down stairs, cut bread, open cans, cut paper, grind meat, screw jar cap,...). Other kinds of machines could be accepted if they are identified.

*__Activities__: Lift a load of books (4#) from the floor to the top of a table or desk. Ask pupils to note how far the load traveled and the force required. List this information on the chalkboard as in Figure 1. Introduce a 6' board and pull the load of books up the inclined plane to the top of the desk (place books on roller skate to reduce friction). Direct pupils to reading (p.8-9) in text to answer question 1 above. Encourage pupils to note that (load x load distance = force x force distance).

After pupils have read pages 22-28, illustrate the inclined plane found in a screw thread. Do this by wrapping the red paper around a roll of newspaper (figure 2). Make another screw thread pattern with the blue paper. Encourage pupils to identify the thread pattern of a screw which will be easiest to use in wood. After they have expressed their ideas, place each cardboard pattern on the bulletin board so that the inclined plane with the least incline will be found to have the greatest number of threads. The winding path up a mountain is similar to the threads on a screw.

As shown in Figure3 , the winding path up the mountain will be longer, but easier for the automobile.

__Results Expected__: If the 4# load is lifted 3', then the 6' inclined plane will require only 3/6 as much force to lift the same load. If the 4# load is lifted 1', then the 6' inclined plane will require only 1/6 as much force to lift the same 4# load.

Fig. 1
Table of Load-Force Relationships

| LOAD | L. DISTANCE | FORCE | F. DISTANCE |
|---|---|---|---|
| 4# | 3' | ? | ? |
| | | | |

I-13

## THIRTEENTH AND FOURTEENTH DAYS --GENERALIZATIONS

1. Friction is a force resisting motion between two surfaces in contact.
2. Friction produces heat.
3. There is some friction in every machine when it is being used.
4. Friction may be classified as: a) sliding friction, b) fluid friction or c) rolling friction.
5. Sliding friction is important in writing, walking, running.
6. Fluid friction is important to objects traveling through air, water, or other fluids.
7. Rolling friction is important to the use of automobiles, roller skates, bicycles.

## CLASS ACTIVITIES

Reading: Read silently and aloud pp. 32-34.

New Words: friction, sliding friction, rolling friction, fluid friction.

Materials: inclined plane, weights, roller skate, hand scale, 2 sheets paper, pencil, chalk, tinker toy boat, pan, water.

Pupil Questions:

1. What is friction?
2. What's the difference between sliding friction and fluid friction?
3. Must 2 objects touch in order to have friction?
4. In Figure 1, which 10# will be easiest to move?
5. When do we need friction?
6. When do we wish to reduce friction?

## CHALKBOARD ILLUSTRATIONS

A. Sliding Friction B. Rolling Friction

Fig. 1

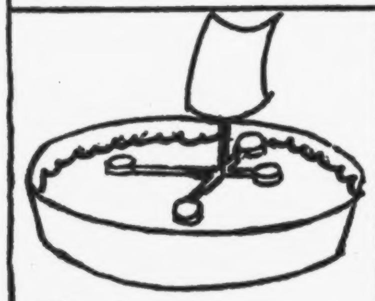


Fig. 2

Tinker-Toy Sailboat

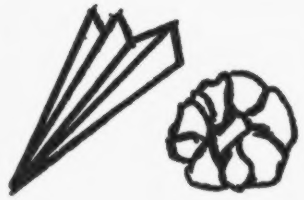


Fig. 3

Airplane Glider and Ball of Paper.

Discussion: Discuss pupils' ideas of the meaning of "friction". Emphasize that the objects must be in contact in order for friction to occur. Identify the friction between two rubbing surfaces as "sliding" friction. The friction between a rolling wheel and some surface is called "rolling" friction. Call attention to the boat and water friction as an example of "fluid" friction.

Ask pupils to idencify the class of friction which occurred when the airplane glider fell to the ground (fluid friction). Discuss the importance of having friction and some of the problems people would encounter if friction disappeared. Have pupils suggest situations in which friction should be reduced.

Activities: Use an inclined plane to lift a load of books. After writing load and lifting force on chalkboard, repeat demonstration using roller skates. Ask pupils to explain why it was easier to lift the load with the roller skates. Call attention to amount of surface contact in each situation. Have one or more pupils try to write their name on glass or window with chalk or pencil. Encourage pupils to explain why this can not be done.

Place tinker toy boat in center of pan as shown in Figure 2. Set toy flag upright. Have one or two pupils attempt to blow the boat from one end of the pan to the other. When pupils are unable to do this, remove boat and add a small amount of water to the pan. Replace the boat and flag in pan. Boat may be easily blown across the surface of the water. Encourage pupils to explain why the boat could be moved easily.

Select two sheets of white paper (8x11). Form one sheet into an airplane glider as shown in Figure 3. Crumple the other sheet into a round ball. Hold each of these above your head and allow them to fall to the floor. Encourage pupils to guess which one will touch the ground first and offer their reasons. Repeat several times.

Results Expected: The same load will require less force to move up the inclined plane on roller skates than to be dragged up the inclined plane. The more surface contact between objects, the greater will the friction be. The smooth glass offers small resistance to the chalk or pencil. The roughness of paper or the chalkboard is needed for each.

Friction between the pan and the boat prevent movement from the slight force of the pupils' breath. However, the fluid friction between the water and the boat is readily overcome by the force of their breaths. Airplane offers less resistance to air than crumpled paper.

**FIFTEENTH DAY - SHOW FILMSTRIP #1 (Frames 27-43) "FRICTION" (JAM HANDY, DETROIT, MICH.) - HAVE CAPTIONS READ ALOUD IN CLASS**

THIS PAGE INCLUDED THE EXACT TEXT USED IN THE CAPTIONS OF THE FILMSTRIP. USING THIS TEXT, THE TEACHER COULD PREVIEW MAIN IDEAS TO EMPHASIZE IN THE FILMSTRIP. THE TEXT IS NOT INCLUDED HERE IN ORDER TO AVOID INFRINGEMENT OF JAM HANDY COPYRIGHT.

## SIXTEENTH AND SEVENTEENTH DAY --GENERALIZATIONS

1. Work is the product of a force and the distance through which it moves.

## CLASS ACTIVITIES

Reading: Show filmstrip #1 "Work and Friction"; frames 1-26.

New Words: work, foot-pounds.

Materials: inclined plane, weights, pulleys, hand scale, bathroom scale.

Pupil Questions:

1. Why do we use "foot-pounds" as a unit for work?

## CHALKBOARD ILLUSTRATIONS

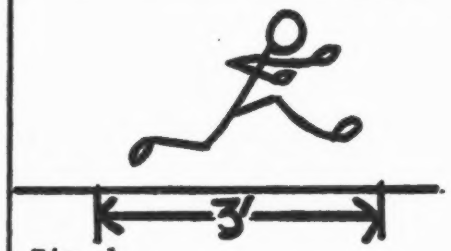


Fig. 1
Stick Man Jumps 3 Feet

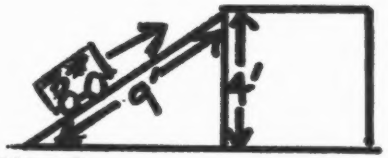


Fig. 2
3 lb. Load is Raised 4 Feet

Discussion: Call attention to the fact that since work requires some force and some distance, different amount of work are measured in foot-pounds. After two or three examples are written on the chalkboard, some pupils will be able to generalize that work is computed by multiplying the force times the distance.

When the book is lifted three feet, nine foot-pounds of work has been done. If the same three pounds is moved up a nine-foot inclined plane, it will require only 1# of effort force. Some pupils will recognize the relationship:

(load) X (distance) = (effort) X (distance).

*Activities: Review briefly pupils' understanding of term "work", which refers to some force moving through some distance. Explain that the scientist measures work by considering the force and the distance it moves. Have one pupil come to front of the room and weigh him. Note his weight on chalkboard as shown in figure 1. Ask him to jump as far as he can from a standing position. Measure this distance to the nearest foot and write this on the chalkboard. Explain that the scientist would say that (___) foot-pounds of work had been done. Repeat this with two or more children.

Make up several different instances where a force or load is moved through some distance. Lift a 3# book approximately 3 feet to a table or desk. Note the amount of work done. Use an inclined plane and roller skate to raise the 3# load up to the table top. When pupils agree that the simple machine made the work easier, call attention to the difference in force required to raise the load without the machine and with the machine. Determine the amount of work done. Measurements should be accurate to nearest foot or pound. Repeat with other loads and determine the work done in each instance.

Expected Results: If a 60# boy jumps three feet, then he will have done 180 foot-pounds of work. If a 70# girl jumps three feet, she will have done 210 foot-pounds of work, The boy may have put just as much effort and determination into his leap as the girl. However, as the scientist defines work the girl did more work because she moved a larger weight just as far as the boy.

| LOAD | DISTANCE | WORK DONE |
|---|---|---|
| A. 50# | 2' | 100 FOOT-POUNDS |
| B. 3# | 4' | ? ___ |
| C. 12# | ? ___ | 60 FOOT-POUNDS |
| D. ___ | ___ | ___ |

Fig. 3
Table Shows Load, Distance, Work Relationships

## EIGHTEENTH DAY - SHOW FILMSTRIP #1 (Frames 1-26) "FRICTION" (JAM HANDY, DETROIT, MICH.) - HAVE CAPTIONS READ ALOUD IN CLASS

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## MATERIALS INCLUDED IN KIT FOR MACHINES UNIT

2 wooden rods
10' rope
2 sections 5' rope
10' lever
2 levers for pupils
8 washers
hand spring balance

2 single pulleys
1 double pulley
twine
box of bolts
wrench
4 screwdrivers
2 paper inclined planes

6' or 4' inclined plane
roller skate
2 sheets of paper
tinker toy boat
pan
3 filmstrips
wood blocks with bolt
wood blocks with hook eye

35 textbooks: Bertha M. Parker, Machines, Harper and Row, Peterson, Evanston, Ill., 1962, 36 pages.

## I-18

# UNIT PLAN OF INSTRUCTION ON TOPIC OF ELECTRICITY

BY:

Gary R. Smith
Associate Professor
College of Education
Wayne State University
Cooperative Research Project 2409

11/65

I-19

## SUGGESTIONS FOR TEACHING UNIT

1. Begin each day with a question, illustration, or activity which will capture the interests of the pupils. Whenever possible utilise questions or objects brought to class by your pupils.
2. Elicit possible explanations or answers from several pupils. Don't tell answers immediately. Ask a child to explain, illustrate or give reasons for accepting a particular answer.
3. Guided by your judgment and the teaching circumstances, give as many pupils as possible an opportunity to do the activities.
4. Use the science textbooks to expand their understanding of the ideas introduced in class. The appropriate text material is to be read silently and then aloud.
5. The concepts presented in Column #1 are intended for the teacher's guidance. They are not to be copied by the children as something to memorise. It is hoped that the pupils will begin to make similar generalisations as a result of the activities, the class discussions and their reading. Encourage your pupils to generalise; but also urge them to use the vocabulary and expressions which are meaningful to them.
6. If circumstances permit, place apparatus in a science corner where children may repeat the activities during their free time.
7. The chalkboard illustrations may be sketched on large newsprint or at the board.
8. Don't try to make your pupils "Electricity Experts." Help them to conclude their study with a feeling that they've learned a great deal about electricity. They've learned the explanations for many things which they previously had taken for granted. However, there are still many things which they don't know about electricity. Help them to close the unit with an interest in continuing the study of electricity.

FIRST DAY -- **GENERALIZATIONS**

1. Electricity produced by rubbing one material with another material is called static or frictional electricity.
2. All matter is made of atoms.
3. Every atom has a nucleus.
4. Around each nucleus of an atom are electrons.
5. The nucleus of an atom has a positive electrical charge.
6. The electrons around the nucleus have a negative charge.

CLASS ACTIVITIES

Reading: View and read frames 1-17 of filmstrip #1, "What Is Static Electricity?"

New Words: matter, atom, nucleus, proton, electron, theory

Materials: Combs, wool or nylon cloth, newspaper, pencils, balloons, filmstrip projector.

Pupil Questions:
1. How big is an atom or an electron?
2. Why does the balloon or newspaper stick to the wall?

CHALKBOARD ILLUSTRATIONS

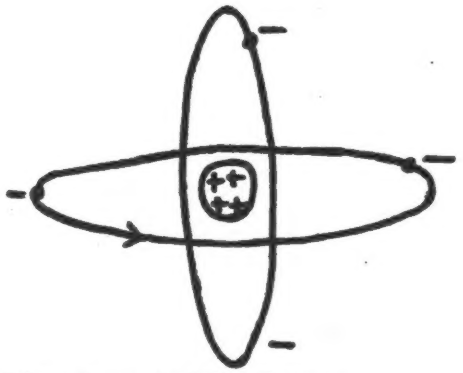


Fig. 1 -- Model of Atom

Discussion: Accept pupils' explanations of the class activities and suggest that they will soon discover if they have been correct. Encourage pupils to offer many of the key words (static, attract, atom, electricity). When the filmstrip is shown, have one or more pupils (good readers) read the captions aloud. If time permits, ask one or more pupils to point to objects in the filmstrip with a pointer. This helps some students to relate a label to a visual object. After the filmstrip, add to the list of words on the chalkboard any new words encountered in the filmstrip. Call attention to the fact that a "theory" is an explanation of why things happen as they do. However, emphasize the tentative nature of theory. The electron theory has been very useful in explaining nature, but it may be changed. Students should be aware of this tentative quality of theories.

Identify the different parts of the atom (nucleus, electron, proton) shown in filmstrip. Help pupils realize that the rings around the nucleus simply show the path of the electrons.

*Activities: Blow up a balloon in class. Rub it on your clothes and place it against the wall. After discussing this, have one or two other pupils repeat this feat. Ask for explanations for this activity. Have a girl with long hair pass a comb through her hair and note the crackling or hair standing on end.

Place a sheet of newspaper on the wall and rub it with the side of a pencil. When the paper adheres to the wall, encourage pupils to suggest explanations.

Use frames 1-17 in Filmstrip #1 "What is Static Electricity?" to introduce the electron theory.

Results Expected: The balloon will adhere to the wall. It will not draw near to other balloons which are brought close to it. The newspaper will also adhere to the wall because of the static electricity which was created by rubbing. In each instance, a rubbing or friction occurred between two surfaces. Since some objects give up electrons readily and others collect them readily, the result of rubbing two different materials was to make them oppositely charged.

## SECOND DAY -- GENERALIZATIONS

1. Neutral objects are neither positively nor negatively charged.
2. A neutral substance becomes negatively charged when it takes on additional electrons.
3. A substance becomes positively charged when it gives up electrons.
4. Neutral objects can be attracted by either positively or negatively charged objects.

## CLASS ACTIVITIES

Reading: Read pp. 3-7 silently and aloud.

New Words: neutral, positive, negative, electrical charge, repel, attract.

Materials: combs, wool or nylon cloth, balloons, thread.

Pupil Questions:
1. Which balloon (A,B,C) is neutral in Fig. 1?
2. Why do the balloons repel one another?

## CHALKBOARD ILLUSTRATIONS

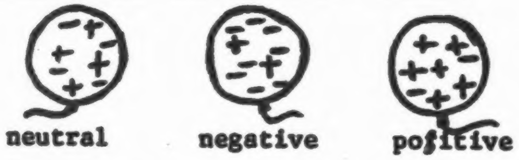
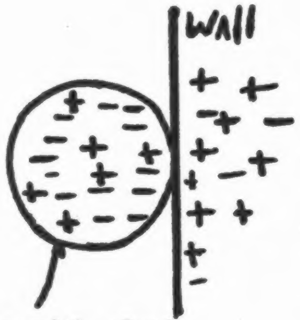


Fig. 1 -- Balloons have different charges

Fig. 2 -- Opposite Charges Hold Balloon to the Wall



Discussion: Review briefly the key terms which had been encountered on the previous day. Use the activities to build meanings of the new words. Illustrate the meaning of "attract" by noting the balloon move toward the wall or toward the person holding it. Illustrate "repel" by noting the two balloons pushing away from one another. Arbitrarily establish the agreement that rubbing the balloon with the cloth makes it "negative." Then, anything which repels the negative balloon is also negative.

*Activities: Have one or more pupils repeat the task of attaching a balloon to the wall. Emphasize the importance of repeating experiments to be convinced that some event occurs consistently. Tie a string around an inflated balloon and rub it with a nylon cloth. Tie the string so that the balloon floats freely in the air. Then bring several objects close to the balloon and note its attraction to the objects. Inflate another balloon and rub it with the same cloth. Note that the two balloons repel.

Read the textbook and help pupils to answer questions briefly as they are posed in the text, by other pupils, or by you. Use the drawings to illustrate the excess (-) charges on negative object. Help pupils to recognize that a charge is a force which "pushes" or "pulls" some object.

Hold two uninflated balloons side by side. Note that they do not attract one another. Establish this as the meaning of "neutral." Inflate one of the balloons and tie a string to it so that the inflated balloon may be suspended in midair. Rub balloon with cloth. Note that inflated balloon now attracts uninflated balloon. Help pupils to generalize that charged objects attract "neutral" objects.

Results Expected: The inflated rubber balloons readily acquire electrons from the cloth to build a negative charge on the balloon. Since a charged object attracts neutral or opposite charged objects, the balloons will draw toward almost all objects offered by the children.

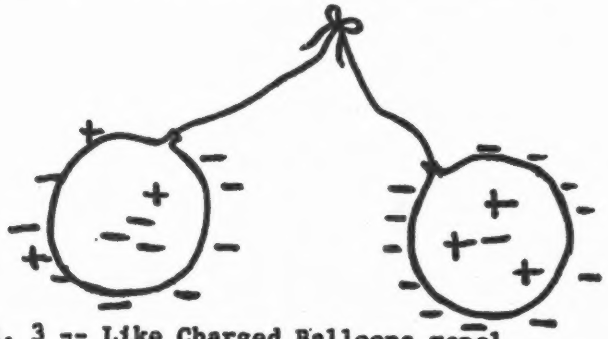


Fig. 3 -- Like Charged Balloons repel

THIRD DAY -- **GENERALIZATIONS**

1. Some materials readily give up electrons, while other materials readily capture electrons.
2. Electrical charges collect on the surface of a material.
3. Like electrical charges repel each other, but unlike electrical charges attract.

CLASS ACTIVITIES

Reading: Complete reading of pages 3-7.

Materials: Tinker toys, balloons, thread, cloth.

Pupil Questions:
1. Do atoms really look like the Tinker Toy models?
2. In Fig. 1, what is the charge on balloons A,B,C,D?
3. Which balloons will attract one another?

CHALKBOARD ILLUSTRATIONS

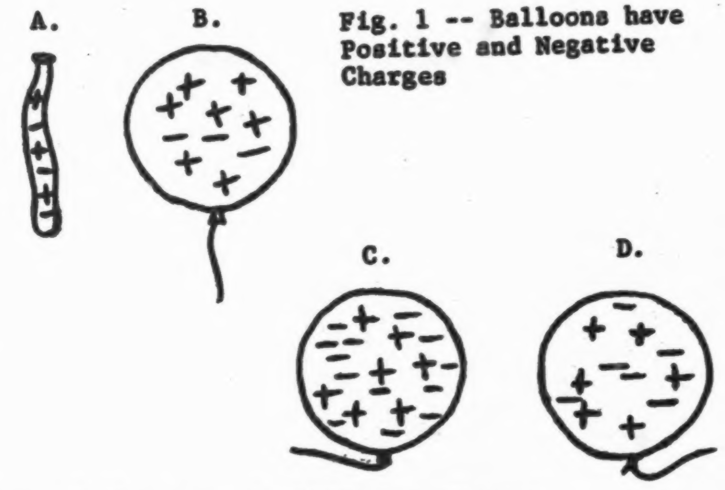


Fig. 1 -- Balloons have Positive and Negative Charges

Discussion: Review briefly the structure of the atoms. Re-emphasize the idea that this is also a theory. Utilize the tinker toys to build models of different atoms for materials which are readily known to the pupils (hydrogen 1e, helium 2e, carbon 6e, oxygen 8e, aluminum 13e). Other elements have many more electrons (copper 29e, silver 47e, gold 79e, nobelium 102e). Help pupils to generalize that the number of elements and their structures determine largely what an element is or can do. Help them to understand that this structure determines whether or not some materials will readily give up electrons and other materials try to capture electrons.

*Activities: Use tinker toys to make models of the atoms for different elements. Pupils should have meaningful associations with most of these elements, i.e. helium used in balloons, diamonds and coal are carbon, oxygen we breath, aluminum foil. Start with simple hydrogen and use the large round part for nucleus. Rods of varying lengths can be used to illustrate distance of electrons from nucleus. Teacher may use Fig. 2 as guide to making models of elements.

Results Expected: Tinker toys provide crude models of atomic structure. Call attention to the fact that the nucleus has many parts contained within it, but for the present we're not examining those closely. This investigation will be undertaken in later studies.

Fig. 2 -- Number of Electrons in Different Elements

| Element | Electrons | Common Use |
|---|---|---|
| hydrogen | 1 | Main part of water, atmosphere |
| helium | 2 | Fill weather balloons |
| carbon | 6 | Found in all living creatures and as coal or diamonds. |
| oxygen | 8 | Found in atmosphere, water |
| aluminum | 13 | wrapping foil, building material |

FOURTH DAY - SHOW FILMSTRIP #1, "WHAT IS STATIC ELECTRICITY?" (JAM HANDY, DETROIT, MICH.) - HAVE CAPTIONS READ ALOUD IN CLASS

THIS PAGE INCLUDED THE EXACT TEXT USED IN THE CAPTIONS OF THE FILMSTRIP. USING THIS TEXT, THE TEACHER COULD PREVIEW MAIN IDEAS TO EMPHASIZE IN THE FILMSTRIP. THE TEXT IS NOT INCLUDED HERE IN ORDER TO AVOID INFRINGEMENT OF JAM HANDY COPYRIGHT.

1

I-24

FIFTH DAY -- **GENERALIZATIONS**

1. Energy is the capacity to do work.
2. Electrical energy is produced by a flow of charged bodies.
3. Electrical energy may change to light energy.
4. When electrons move along a conductor, an electric current is produced.

CLASS ACTIVITIES

__New Words__: conductor, electric current, glow lamp

__Materials__: balloons, glow lamps

__Pupil Questions__:
1. Why does the lamp glow?
2. Why doesn't the lamp stay lighted?

CHALKBOARD ILLUSTRATIONS

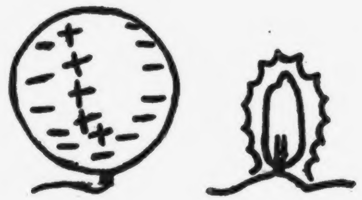
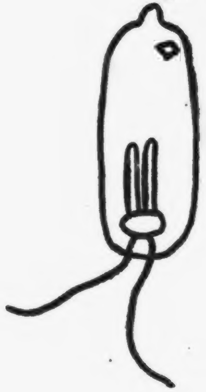


Fig. 1 -- Electrons on Charged Balloon Pass Through Glow Lamp to Make Light.

Fig. 2 -- Magnified View of Glow Lamp



__Discussion__: Help pupils to recognize the sequence of events which preceded the lighting of the glow lamp. That is, an excess of electrons is placed on the charged balloon. The negative balloon is attracted to the neutral wall. When the glow lamp is brought near the balloon, many of the electrons may escape onto the wire of the lamp. As they pass through the lamp, they form an electric current which lights the lamps briefly. Establish the fact that work has been done (lighting the lamp briefly), and the flow of electrons is known as an electric current.

*__Activities__: Place a charge on one of the inflated balloons and attach it to the wall. Darken the room. Hold the glow lamp by the end of one wire and move the other wire up and down the side of the balloon. After pupils have satisfactorily identified the different ingredients in the experiment and explained what occurred, allow several students to repeat the activity at their tables or in front of the room.

__Expected Results__: The results have been stated briefly above. If there was a steady supply of electrons available on the balloon, it would be possible to keep the glow lamp lighted for sometime. This activity may lead directly into a discussion of an electric cell, which does provide the steady supply of electrons.

## SIXTH DAY -- GENERALIZATIONS

1. The chemical changes in an electric cell provide an excess of electrons at the negative terminal and few electrons at the positive terminal.

2. The decrease of electrons at a terminal forms a force which moves electrons along a conductor.

3. Electrons from the negative terminal of a cell will readily flow along a conductor tending to equalize the number of electrons at each terminal.

## CLASS ACTIVITIES

Reading: Read pp. 8-9 silently and aloud.

New Words: electric cell, chemical change, terminals, conductors

Materials: tall dry cell, lamp (1½), bell wire, flashlight cell, "dead" cell

Pupil Questions:
1. What is a chemical change?
2. What's the difference between a cell and a battery?
3. How hot does an electric wire get?

## CHALKBOARD ILLUSTRATIONS

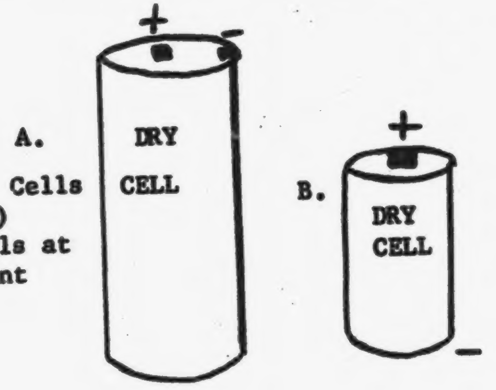


Fig. 1 Cells have (-) terminals at different places

Discussion: Review the importance of having a steady supply of electrons in order to do work. Ask pupils to suggest these sources. Establish that a dry cell is one important source of electrical energy. After reading the text (pp 8-9), help pupils to distinguish between the terms: dry cell and battery. Use chalkboard drawing to distinguish between dry cell and flashlight cell. Have pupils cite examples of chemical change. Call attention to the fact that an electric cell makes a change of chemical energy to electrical energy. Note that the electric current produced light energy and heat energy.

*Activities: Read text pp. 8-9 and interpret pictures in booklet as well as chalkboard illustrations. Take the tall dry cell and use bare wire to connect it to the light bulb terminals as shown in Figure 2. After noting the change of energy forms (chemical energy to electrical energy to light energy) ask a pupil to hold the bare wire to one terminal of the light. When he drops the wire because of the heat, help the class to recognize that heat energy as well as light energy is produced by the flow of electricity.

Illustrate the path of the electrons from the negative terminal of the cell (excess of electrons) to the positive terminal (deficiency of electrons).

Ask one of the pupils to take home a "dead" flashlight cell and take it apart. Ask the pupil to identify the different parts in class on the next day.

Results Expected: The electric current will light the lamp when the circuit is complete. The path of electricity from (-) terminal to (+) terminal is shown in Figure 2. There is not enough electricity in the dry cell to injure any pupil. The passage of electric current through any object will create heat. In this instance, the thin wire becomes hot to the touch. With a lighted flashlight, the amount of heat generated is negligible to the touch.

A chemical change occurs when a new substance is made by combining two or more materials. In the dry cell, the black material is a chemical (manganese dioxide). The silver metal is zinc and the black rod is carbon. The chemical and the zinc react in a chemical change to create an excess of electrons which flows from the zinc, through some conductor, and returns to the cell via the carbon rod.

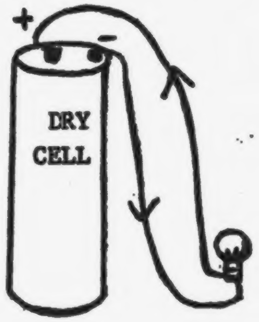


Fig. 2 -- Electrons Flow from Cell, Through Light Bulb, and Back to Cell.

## SEVENTH DAY -- GENERALIZATIONS

1. Since current produced by a cell flows in one direction only, it is called direct current.

2. Alternating current flows first in one direction and then in the opposite direction.

3. Electricity from a generator may be either direct current (DC) or alternating current (AC).

4. Electric current may be used to: heat or cook, make light, send messages, and run machines.

## CLASS ACTIVITIES

Reading: Read pp. 18-20, 23-26.

New Words: alternating current, direct current, generating current

Materials: dry cell, lamp, wire

Pupil Questions:
1. Will the lamp give light when the wires are changed?

2. Why does the bulb glow?

Discussion: Distinguish clearly between direct current and alternating current. The latter is commonly used in homes and businesses. Pupils may have several personal experiences to relate about problems with fuses or electrical fires. Call attention to the thin wire in the light bulb shown on page 20 of the text. Pupils may skim through pages 26-33 to note other applications of electricity in their daily lives.

*Activities: Discuss the various uses of electricity which are illustrated in the pictures of the text. Have one or more pupils come to the front of the room and demonstrate that the lamps will light even when the wires are changed at the terminals of the flashlight cell or at the lamp base.
Make a listing at the chalkboard of the various uses of electricity.

Results Expected: The lamp will light when the terminals are switched or when the wires touching the contacts on the lamp are exchanged. The thin wire in the light bult is a poor conductor which resists the passage of electricity. The electric current heats the wire until it glows white hot and gives light.

## CHALKBOARD ILLUSTRATIONS

Fig. 1 -- Electric Cells Give Direct Current

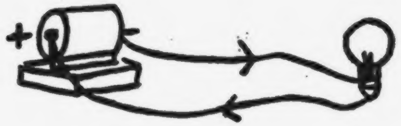


Fig. 2 -- Alternating Current is Used to Light Lamps

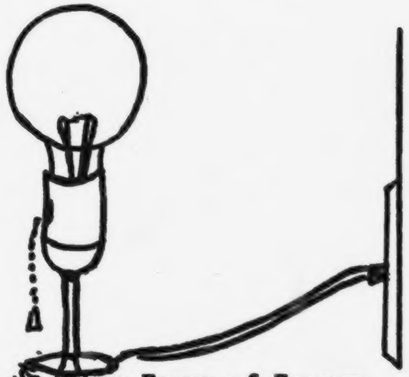


Fig. 3 -- Electrical Energy Changed to Other Forms of Energy

| Energy Change | Example |
|---|---|
| Electrical Energy to Heat Energy | Stoves, irons, heater |
| Electrical Energy to Light Energy | Street light, house lights, car lights |
| Electrical Energy to Mechanical Energy | Motors, machines |

## EIGHTH & NINTH DAY -- CONCEPTS

1. When electrons move along a conductor, an electric current is produced.
2. Current electricity is used more than static electricity.
3. An electric circuit contains a source of electrical energy and a path through which the current may flow.
4. A closed circuit has no gaps in the path of the current of electricity.
5. An open circuit has a gap somewhere in the path of the current.
6. An electric circuit may be connected in series or in parallel.

## CLASS ACTIVITIES

**Reading:** Read pp. 10-15 silently and aloud. Note pictures on pp. 22, 34 35.

**New words:** electric circuit, closed circuit, open circuit, series circuit, parallel circuit.

**Materials:** balloons, neon lamp, compass galvanometer, wire, dry cells, peg board

**Pupil Questions:**

1. What is a circuit?
2. What's the difference between series and parallel circuits?
3. Where are these circuits used?

## CHALKBOARD ILLUSTRATIONS

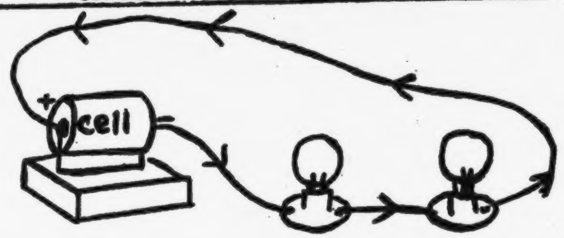


Fig. 1 -- Flow of Electricity in Series Circuit

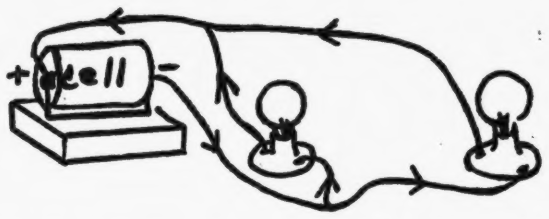


Fig. 2 -- Flow of Electricity in Parallel Circuit

**Discussion:** Call attention to the meaning of "circuit" among the three members (cell, bulb, wire). Ask pupils to note what happens when the wire is removed and the circuit broken. Encourage them to identify this breaking of the circuit with a switch. Pupils should be able to identify several instances when a switch is used to break the flow of electricity through a circuit.

The pictures on pages 10, 11 illustrate a series circuit and switches. Some pupils may identify the error in the text which explains the path of electricity through the flashlight on page 15.

***Activities:** Have one or more pupils come to front of room and connect wire so that a complete circuit is made and the lamp lights. Call attention to the different elements in the circuit, i.e.(source of electricity, path for electron to travel, lamp to light or other work to do).

Distribute a bulb, flashlight cell, and insulted wire to groups of pupils. Ask each group to take turns making the bulb light. Ask them to try different arrangements of bulb, battery and wire.

At the chalkboard, sketch the path of the electrons as they flow from the cell through the wire and bulb and back to the cell. Note that there is a correct path -- start at the negative pole and follow the circuit to the positive pole. Arrange the peg board wiring so that a series circuit (Figure 1) is formed. Note that all lights go out when one light is removed. Next, arrange the lights in parallel. Note that one light will stay lighted even when another bulb is out (Fig. 2).

**Results Expected:** Whenever a circuit is formed the lamp will light. If the pupils don't remove the insulation from the wire, they will not be able to light the bulb. Any switch can be considered as a kind of break in the circuit. Buildings use parallel circuits so that when one light or machine is turned off, all of the other units can continue to operate.

In parallel wiring, all lamps receive the same amount of electricity. Therefore, each lamp has about the same brilliance.

## TENTH DAY -- GENERALIZATIONS

1. All materials offer some resistance to an electric current.
2. An electric current flows easily along good conductors of electricity, but does not flow easily along poor conductors.
3. Most metals are good conductors.
4. When an electric current flows along a wire, the wire is heated.
5. In electrical heating appliances a current is sent along a wire which is a poor conductor.
6. When a large electric current flows along a wire which is a poor conductor, it may become hot enough to give off light.

## CLASS ACTIVITIES

**Reading:** Complete reading pp. 10-15 silently and aloud. Review pp. 23-24.

**New Words:** resistance, insulator, appliances.

**Materials:** dry cells, lamps, wire, nichrome wire

**Pupil Questions:**
1. Why does the nichrome wire get hot?
2. What are some poor conductors or good conductors of electricity?
3. Is a poor conductor useful to people?

## CHALKBOARD ILLUSTRATIONS

Fig. 1 Conductors of Electricity

| Good | Poor |
|---|---|
| copper<br>iron<br>steel<br>most metals | wool<br>glass<br>cloth<br>wood<br>paper |

**Discussion:** Encourage pupils to recognize that some poor conductors will resist the flow of electricity. In some cases they may become red hot. Call attention to the use of thin wires used in light bulbs which are heated to a white heat in a partial vacuum of the bulb.

Review briefly the heat appliances which depend upon electricity. Several are illustrated or described on pages 23-24.

Call attention to the fact that water is a weak conductor of electricity. For that reason, children should never touch any electrical appliance with wet hands. Discuss briefly the safety hazards of electrical energy. Whenever pupils do experiments at home, they should always use dry cells. They should never experiment with electricity from a wall outlet unless a knowledgeable adult is there to supervise.

***Activities:** After defining "conductors" and "non-conductors", distribute bulbs, and wire to several groups and encourage them to identify several specific conductors and non-conductors. List these on the chalkboard. Encourage pupils to generalize that most metals appear to be good conductors, while cloth, wood and paper are poor conductors.

Place a piece of nichrome wire across the terminals of the tall dry cell. Note that it turns red because of the heat.

Each possible conductor can be tested by placing it in the circuit as shown in Fig. 2. If the lamp light, it is a good conductor. Before the test, check to see if the cell and lamp are all right.

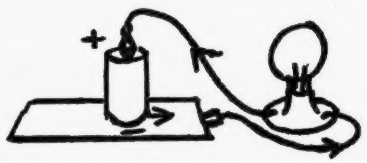


Fig. 2 -- Testing Conductors of Electricity

## ELEVENTH DAY - SHOW FILMSTRIP #4, "PRODUCING SMALL AMOUNTS OF ELECTRICITY" (JAM HANDY, DETROIT, MICH.) - HAVE CAPTIONS READ ALOUD IN CLASS

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**TWELFTH AND THIRTEENTH DAYS -- GENERALIZATIONS**

1. An electromagnet consists of a piece of iron within a coil of wire, along which a current of electricity is sent.
2. An electromagnet has a north-seeking pole and a south-seeking pole, just as other magnets do.
3. An electromagnet can be made stronger by increasing the number of turns of wire wound around the core or by increasing the current.
4. An electromagnet has considerable force only so long as the electric current is flowing.
5. Electromagnets are important parts of electric motors.

**CLASS ACTIVITIES**

Reading: Read pp. 16-17. If time permits skim pp. 25-32 and note uses of electromagnets in motors.

New Words: Electromagnet

Materials: electromagnet, bolts, magnets, nails, 4 dry cells, wire, 2 compasses

Pupil Questions:
1. What makes an electromagnet strong?
2. Where are electromagnets used?

**CHALKBOARD ILLUSTRATIONS**

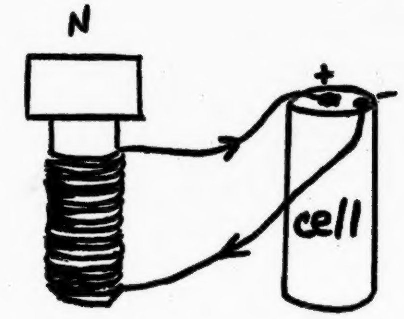


Fig. 1 -- Electromagnet

Discussion: Many of the pupils will have had experiences with magnets previously. These can be reviewed briefly. In the discussion, establish the meaning of a magnet and that it has a north-seeking pole and a south-seeking pole. Pupils may suggest that when a north-seeking pole is brought close to the north-seeking pole of the compass, the compass needle will be repelled. Two compasses may be used to establish the generalization that two north-seeking poles repel and opposite poles of the magnets attract one another.

Ask pupils to suggest how electricity might be used to make a magnet. Often, some pupil will have done this previously. Call attention to the three ingredients for an electromagnet --- iron, insulated wire, electricity.

Encourage pupils to generalize that the electromagnet loses most of its strength when the electricity is removed. They should also recognize that increasing the number of turns from 25 to 75 enables the electromagnet to pick up many more nails.

*Activities: Use the magnet in the kit to demonstrate that it attracts small iron nails and other iron objects. Introduce a compass to identify North and to demonstrate that like poles repel one another. Have one or more pupils wrap an iron bolt with 25 turns of the wire. Test the bolt to be sure it's not a magnet. Connect the ends of the wire to the cell and note that the iron bolt wrapped in wire will attract the small nails when electricity flows through the wire. Pupils should note what happens to the nails when the electricity is stopped. Have one or more pupils wrap iron bolts with wire and attempt to pick up the small nails.

Encourage pupils to increase the number of turns of wire from 25 turns to 75 turns and note what happens when they try to pick up the small nails. The turns of wire should be close together and move from one end of the bolt to the opposite end and return.

Results Expected: The magnet will attract all iron objects. Its N-pole can be readily identified with the compass. The bolt with 25 turns will pick up a small number of nails. When the electricity stops, the nails will be released because the electromagnet has lost most of its strength. Some slight magnetism may remain, but this is negligible.

Increasing the number of turns to 75 will triple the strength of the electromagnet, although it may not be able to pick up three times as many nails in every case. The important generalization to make is that increasing the number of turns increases the strenght of the electromagnet.

The North-seeking pole of the electromagnet can be identified by bringing it close to the North-seeking pole of the compass.

I-31

## FOURTEENTH DAY --GENERALIZATIONS

1. A magnetic field around a wire is created by sending a current of electricity through the wire.

## CLASS ACTIVITIES

**New Words:** magnetic field

**Materials:** wire, cells, magnets, compasses, nails

**Pupil Questions:**
1. Do all magnets have magnetic field?
2. Can I see the magnetic field?

**Discussion:** Ask pupils to offer their explanations of the meaning of "magnetic field." Encourage pupils to suggest occasions when they've heard the term mentioned, i.e. earth's magnetic field, iron filings scattered over bar magnet.

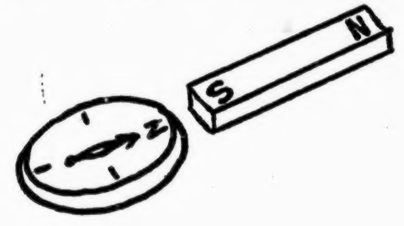
***Activities:** Distribute the compasses to one or more pupils and have them align the North and South-seeking poles. Bring a small bar magnet close to the compass (as in Fig. 1) and keep it two or three inches above the compass. Ask pupils to explain what happens to their compass needle when the N-pole of the bar magnet points N,S,E, or W.

Place the bar magnet far away so it will not affect the needle. Have pupils align the N-pole of the compass again. Have pupils place a wire over the top of their compass in a North-South direction (Fig. 2A). Ask pupils to touch the ends of the wire to the terminals of their flashlight cell (Fig. 2B) and tell what happened. After repeated trials encourage pupils to generalize that the electric current passing through the wire created a magnet. After noting which direction the North-seeking pole of the compass traveled when electricity was flowing, have pupils attach the wires to the opposite terminals.

**Results Expected:** The poles of the bar manget will attract the opposite poles of the compass. When the N-pole of the bar magnet points West, the South-pole of the compass will point West.

## CHALKBOARD ILLUSTRATIONS

Fig. 1 -- Opposite Poles of Magnets Attract



When the electric current passes through the wire, a magnetic field is created around the wire. This causes the compass needle to be deflected at right angle to the wire. If the wire is connected so that electricity flows from S-pole to N-pole, then the compass's North-pole will point West when electricity is flowing through the wire. The compass needle reverses its direction when the connections to the cell terminals are reversed.

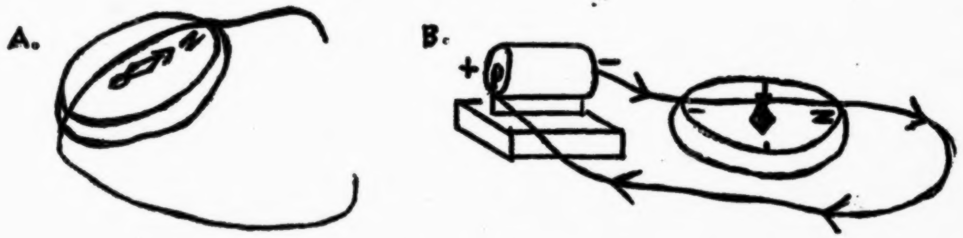


Fig. 2 -- Before Electricity Flows Through Wire (A)
After Electricity Flows Through Wire (B)

### FIFTEENTH DAY - SHOW FILMSTRIP #3, - "ELECTROMAGNETS AND HOW THEY WORK" (JAM HANDY, DETROIT, MICH.) - HAVE CAPTIONS READ ALOUD IN CLASS

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## MATERIALS INCLUDED IN KIT FOR ELECTRICITY UNIT

8 flashlight cells
2 dry cells
10 flashlight bulbs
1 package of balloons
100' wire
6" nichrome wire
25' roll aluminum wire

10 glow lamps
4 bolts
1 wool cloth
1 motor (1-1/2 v. D.C.)
10' thread
10 compasses
2 combs

8 screwdrivers
3 filmstrips
1 electricity board
1 magnet (flexible)
1 carphone
aluminum foil
tinker toys
bolts and nails

35 textbooks: Bertha M. Parker, Electricity, Harper and Row, Peterson, Evanston, Ill., 1963, 36 pages.

### I-34

# UNIT PLAN OF INSTRUCTION ON TOPIC OF HEAT

BY:

Gary R. Smith
Associate Professor
College of Education
Wayne State University
Cooperative Research Project 2409

3/66

# SUGGESTIONS FOR TEACHING UNIT

1. Begin each day with a question, illustration, or activity which will capture the interests of the pupils. Whenever possible utilize questions or objects brought to class by your pupils.
2. Elicit possible explanations or answers from several pupils. Don't tell answers immediately. Ask a child to explain, illustrate or give reasons for accepting a particular answer.
3. Guided by your judgment and the teaching circumstances, give as many pupils as possible an opportunity to do the activities.
4. Use the science textbooks to expand their understanding of the ideas introduced in class. The appropriate text material is to be read silently and then aloud.
5. The concepts presented in Column #1 are intended for the teacher's guidance. They are not to be copied by the children as something to memorize. It is hoped that the pupils will begin to make similar generalizations as a result of the activities, the class discussions and their reading. Encourage your pupils to generalize; but also urge them to use the vocabulary and expressions which are meaningful to them.
6. If circumstances permit, place apparatus in a science corner where children may repeat the activities during their free time.
7. The chalkboard illustrations may be sketched on large newsprint or at the board.
8. Don't try to make your pupils "Heat Energy Experts." Help them to conclude their study with a feeling that they've learned a great deal about heat energy. They've learned the explanations for many things which they previously had taken for granted. However, there are still many things which they don't know about heat energy. Help them to close the unit with an interest in continuing the study of heat energy.

I-36

## FIRST DAY -- GENERALIZATIONS

1. The sun transfers a great deal of heat energy to earth.
2. Chemical changes, electricity and friction are common sources of heat.
3. Heat energy may be changed to other forms of energy such as light, chemical, electrical, mechanical energy.
4. Heat energy is the energy which moving molecules are able to transfer.

## CLASS ACTIVITIES

**Reading**: Read pp. 5-7 and pp. 12-18 silently and aloud. Discuss pictures.

**New Words**: Heat energy, transfers, molecules, chemical change

**Materials**: matches, dry cell & nichrome wire, water, light bulb and socket.

**Pupil Questions**:
1. What is heat?
2. Where do we get heat?

## CHALKBOARD ILLUSTRATIONS

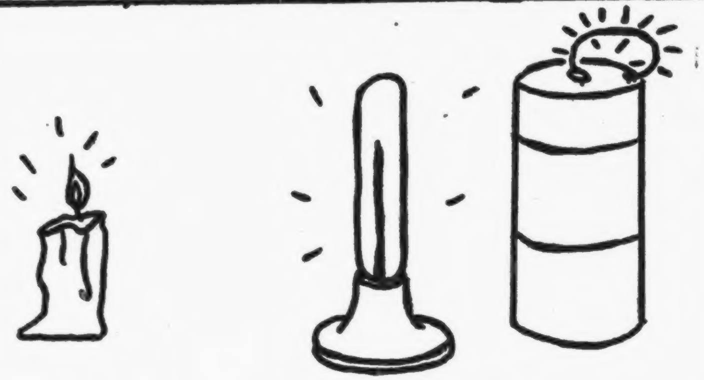


Fig. 1 Sources of heat energy.

**Discussion**: Initiate discussion by asking pupils what they believe heat is. Accept their suggestions. Then make a list of some examples of heat at the chalkboard (See Table 1 at right). After several examples of heat have been listed, encourage pupils to suggest how heat was produced in each instance. Pages 12-18 in the textbook will help pupils recognize that energy may change its form.

**Activities**: Have pupils rub their hands toghther and note the friction produces heat. Take a match from the kit and rub it quickly across some rough surface. Encourage pupils to explain why the match lighted and what kind of energy was being converted to heat energy in the flame. Illustrate the change of electrical energy to heat by lighting the light bulb and noting the white hot filament. If time permits connect a bare wire to the terminals of a dry cell and let pupils see the wire glow from the heat created by the flowing electrons.

**Results Expected**: Most pupils will recall from previous study that heat was produced by friction when they rubbed their hands together. Rubbing the match on a rough surface creates enough heat to ignite the phosphorous in the match. The resulting chemical change produces enough intense heat to start the wood burning. This is mechanical energy (friction) producing a chemical change (chemical energy) which in turn yields heat energy. However, rubbing the match on a smooth surface would produce less friction and less heat. Ordinarily, the amount of heat would not be enough to ignite the phosphorous.

Electrons passing through the wire create intense heat which causes the wire to give light.

Table 1 Events Which Produce Heat

| Example | Source of Energy |
|---|---|
| sun shining | chemical energy |
| lighted match | chemical energy |
| explosions | chemical energy |
| gas & oil fires | chemical energy |
| electric lamps shining | electrical energy |
| toaster in use | electrical energy |
| friction between hands | mechanical energy |

## SECOND AND THIRD DAY -- GENERALIZATIONS

1. Matter exists in three states: solids, liquid, gas.
2. Matter is made up of atoms which combine to form molecules.
3. Molecules spin and move very fast.
4. In a solid, molecules are locked tightly together by mutual attraction.
5. In a liquid, molecular attraction is reduced and molecules flow past one another.
6. In a gas, molecular attraction is very weak and molecules move freely and rapidly.

## CLASS ACTIVITIES

**Reading**: Read pp. 8-11 silently and aloud.

**New Words**: matter, gas, atoms, attraction

**Materials**: candle, beaker, water, 2 plastic bags, ice, cloth, hot plate, moth balls, ammonia.

**Pupil Questions**:
1. What is the difference between a solid, liquid, gas?
2. Why can I smell a moth ball?

## CHALKBOARD ILLUSTRATIONS

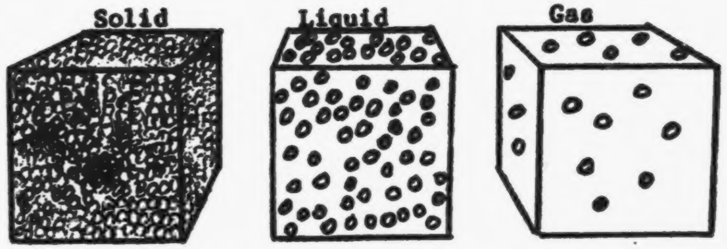


Fig. 1 Examples of molecules arranged in solid, liquid, gas.

**Discussion**: Review briefly the earlier discussions that all matter is made of atoms which combine to form molecules. Help pupils to recognize that another way to classify objects is to think of them as solids, liquids, or gases. During the discussion, make a list at the chalkboard of the different objects which would roughly be classified as solid, liquid or gas.

Encourage pupils to generalize that solids as well as liquids may be colored, occupy space, and may be weighed. Although solids retain their shape liquids readily change their shape. Remind pupils that a book retains its shape when placed on a table or in a plastic bag. Have pupils note that when water is poured into the bag or onto the table, it takes the shape of the object which it encounters. In liquids and gases, the molecules are far enough to flow past one another.

**Activities**: Collect some air into one of the plastic bags and close the open end of the bag. Have one or more pupils feel the bag of air. Transfer the air from one bag to the other in order to convince pupils that air and most other gases are invisible---but they do occupy space.

Select an ice cube and identifyit as a solid. Place the ice cube on a hot pan and have one or more pupils identify the changes from solid state to liquid to gas (Fig. 2).

Place some ammonia onto a cloth and have pupils raise their hands when they detect its odor. Call attention to the fact that this is an example of a liquid changing to a gas and entering our nostrils to produce the impression of ammonia. If time permits, conduct the same activity with 3 or 4 moth balls which are instances of a solid changing to a gas.

**Results Expected**: The air in the plastic bag can be readily moved from one bag to another. Since a gas occupies space and takes the form of the objects which it encounters, the plastic bag will be filled with air. The ice cube will change state from a solid to a liquid and finally evaporate to become a gas. This is the common change of state. However, some solids may change directly to a gas. This is illustrated in the case of ammonia or moth balls. As the gas from the moth balls spreads throughout the room, most pupils will be able to detect the odor.

Be very careful with ammonia and moth ball. Both are poisonous if taken internally.

Table I -- Examples of the 3 States of Matter

| Example | State |
|---|---|
| desk | solid |
| pencil | solid |
| water | liquid |
| coke | liquid |
| paper | solid |
| air | gas |
| wind | gas |
| rain | liquid |

## FOURTH DAY - SHOW FILMSTRIP #1, - "CAUSES AND NATURE OF HEAT" (JAM HANDY, DETROIT, MICH.) - HAVE CAPTIONS READ ALOUD IN CLASS

THIS PAGE INCLUDED THE EXACT TEXT USED IN THE CAPTIONS OF THE FILMSTRIP. USING THIS TEXT, THE TEACHER COULD PREVIEW MAIN IDEAS TO EMPHASIZE IN THE FILMSTRIP. THE TEXT IS NOT INCLUDED HERE IN ORDER TO AVOID INFRINGEMENT OF JAM HANDY COPYRIGHT.

## FIFTH DAY -- GENERALIZATIONS

1. In general, all matter expands when it is heated and contracts when it is cooled.
2. Adding heat increases the speed of the molecules in a material.
3. A solid may be changed to a liquid or gas by adding heat energy.
4. Removing heat from a substance will decrease the speed of the molecules.
5. Removing heat from a material will cool it.
6. A gas may be changed to a liquid or a solid by removing heat energy.

**Reading**: Review ideas on pp. 8-11.

**New Words**: expand, contract

**Materials**: balloons, large can, tube, bottle, water, food coloring, hot plate

**Pupil Questions**:
1. Why did the balloon become larger?
2. Why did the balloon become smaller?

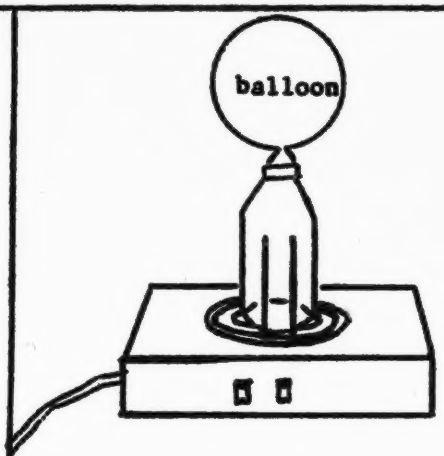


Fig. 1 Air in bottle expands to fill balloon.

**Discussion**: As each activity is completed, call attention to the common factor that adding heat ordinarily causes expansion and removing heat causes contraction. Review briefly the idea developed in a preceding lesson (changing ice cube to gas) that adding sufficient heat will cause a solid to become a liquid and finally a gas. This may be reversed by removing heat to make a gas into a liquid and finally into a solid. An example of the latter would be the frost which forms on windshields in the winter. In this situation, the warm air (a gas) near the windshield is cooled as the temperature drops and forms drops of water (liquid) on the windshield. As the temperature continues to fall, the droplets of water are frozen to form ice crystals (solid) on the windshield.

**Activities**: Place a balloon over the mouth of a container (Fig. 1 ). Place can on hot plate and ask pupils to explain why balloon begins to expand. Ask pupils to suggest ways in which they can teturn balloon to its original (uninflated) state.

Place tube inside bottle which has been filled with colored water. Note level of water in tube. Place bottle on hot plate and note water rising in tube (Fig. 2). Cool bottle and note change in level of water.

**Results Expected**: Heating the can will cause the air inside the can to expand. Since the air cannot escape, it will cause the balloon to expand. Cooling the air inside the can will cause the air to contract. This means that it will occupy less space and the balloon will collapse.

Heating the liquid inside the bottle causes the liquid to expand.

Because the tube has a very small passage, it is possible to see the effect of this expansion.

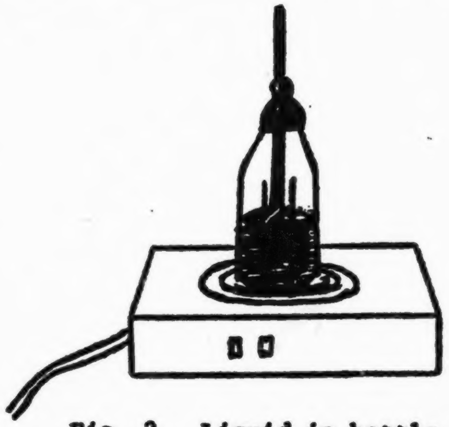


Fig. 2 Liquid in bottle expands and rises in tube.

**SIXTH DAY -- GENERALIZATIONS**

1. Removing heat from water causes it to contract until 4° C and then water expands until it reaches 0° C.
2. Evaporation is an important way to cool something.

**CLASS ACTIVITIES**

**Reading:** Review ideas on pp. 8-11.

**New Words:** evaporation

**Materials:** jar with threaded cap, newspaper, bottles of alcohol and water, cotton.

**Pupil Questions:**
1. What is evaporation?
2. Where does evaporation occur?
3. Why does thermometer dipped in alcohol cool faster than one dipped in water?

**CHALKBOARD ILLUSTRATIONS**

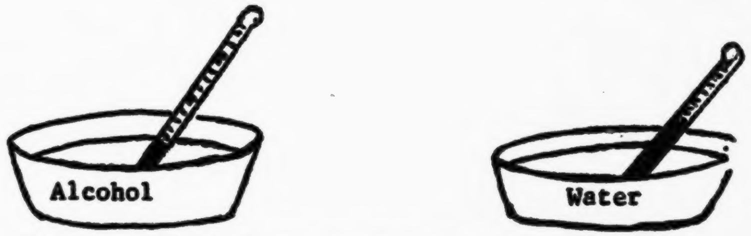


Fig. 1 Alcohol evaporates more rapidly than water.

**Discussion:** Pupils may cite instances when they have noted water evaporating from aquarium or from streets after rain. Some pupils may have had an alcohol rub to reduce their body temperature when they have had a fever. Clouds are formed by evaporation of water from surface of the earth.

The fact that water expands just before it reaches 0° C is important in causing ice to float on water. The resulting ice (a solid) occupies more space than it did as a liquid. The ice is less dense than the surrounding water, which pushes the ice to the surface.

**Activities:** Use a cotton swab to place a few drops of water on wrist of pupil. Fan the wrists with a cardboard to make the water evaporate quickly. Ask pupils to explain their sensations. Repeat the activity but use drops of water on one wrist and drops of alcohol on the other wrist. Ask the pupil to explain his sensations and to note which liquid evaporated first.

Place thermometer into alcohol and into water. Remove thermometers and note which temperature falls rapidly. (See Fig. 1)

Fill large glass bottle with water and screw the lid tightly onto the bottle. Wrap the bottle in newspaper and place it in a freezing compartment. Examine the broken bottle the next day and ask pupils to account for the breakage.

**Results Expected:** When water begins to evaporate, the temperature of the wrist will be reduced and pupils will report a cool sensation. When water and alcohol are placed on the wrists, the wrist having the alcohol will appear to feel cooler. This is because alcohol evaporates faster than water.

The temperatures of both thermometers will drop, but alcohol thermometer will drop faster because alcohol evaporates faster than water.

## SEVENTH DAY -- GENERALIZATIONS

1. The amount of heat energy in a material can be measured.
2. Touching, seeing, or other senses are not accurate ways to measure temperature.
3. Temperature is not a measure of the total amount of heat in a material.

## CLASS ACTIVITIES

**Reading**: Read pp. 19-25 silently and aloud.

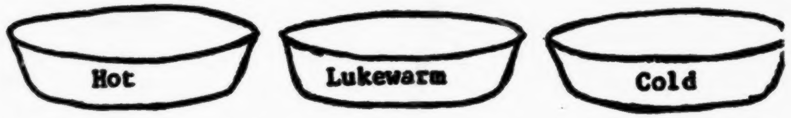
**New Words**: temperature, senses, accurate, average speed.

**Materials**: 3 pans, jar of lead, water, paraffin, hot plate, Pyrex bowl, tongs

**Pupil Questions**:
1. Why is the same pap of water called "lukewarm" and then "hot" and "cold"?
2. Why does one jar sink deeper than the other jar?
3. Are water molecules moving fastest in "cold," "warm" or "hot" water?

## CHALKBOARD ILLUSTRATIONS

Fig. 1 Pans of water to test sense of heat



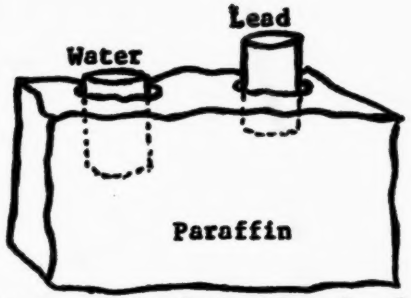


Fig. 2 Water and lead absorb and release different amounts of heat.

**Discussion**: The first activity emphasizes the fact that our senses are often deceptive, Help pupils to recognize that initially the pupils "sensed" that the middle pan of water was "lukewarm." Finally, one hand "sensed" that the same pan of water was "cold or cool" and the other hand reported it to be "warm or hot". Emphasize the unreliability of certain sensations. Pupils may be able to identify other sensory deceptions, i.e. mirages, optical illusions, television sound effects.

The jars of water and metal illustrate the idea that objects, which have the same size and temperature may possess different amounts of heat energy. Large objects will possess more heat energy than smaller objects of the same material. This is also illustrated by the fact that Lake Michigan possesses more heat energy than a burning match, even though the match is at a substantially higher temperature than the water in the lake.

**Activities**: Fill three pans with water (hot, lukewarm, cold). Have a pupil place both hands into the lukewarm water for about 30 senonds. Then, have him place his left hand into the pan of hot water and his right hand into the pan of cold water. Ask him to describe his sense of hot or cold. Allow hands to remain in hot and cold pans for 1 or 2 minutes. Quickly remove both hands, dry them, and place both hands into lukewarm water immediately. Once again ask pupil to report sense of hot or cold for each hand.

Allow one or more pupils to examine jars of water and lead. Place jars into container of boiling water. Allow 5 minutes for jars to attain temperature of boiling water. Establish fact that both jars have same temperature. Place jars onto bar of paraffin. Encourage pupils to estimate which jar will melt the most paraffin and why. Place a large and small object of same material onto bar of paraffin, after heating them. Note which melts most paraffin.

**Results Expected**: The pupil will identify the lukewarm water as such. Next, his left hand will sense "hot" and his right hand will sense "cold". However, when both hands are returned to the lukewarm water, the left hand senses "cold" and the right hand senses "hot." The pupil's senses are merely reporting changes and not measuring temperature.

The jar of water will melt more paraffin. Since the water has absorbed more heat energy than the lead, it has more heat to release than does the lead. Obviously, a large container of water will absorb more heat than a small jar of water.

## EIGHTH AND NINTH DAYS -- GENERALIZATIONS

1. Thermometers are used to measure temperature.

2. Thermometers can be made by using air and water, alcohol, metals.

3. Fluids in a thermometer indicate temperature changes by expanding when heated and contracting when cooled.

4. The Fahrenheit scale and Centigrade scale are two common ways of marking thermometers.

## CLASS ACTIVITIES

Reading: Read pp. 19-25 silently and aloud.

New Words: fluid, thermometer, Fahrenheit, Centigrade

Materials: Water, food coloring, tubing, bi-metallic strip, hot plate, bottle, thermometers , alcohol thermometer Ben Franklin Thermometer

Pupil Questions:
1. What's the difference between Centigrade and Fahrenheit thermometers?
2. Why isn't water used to make thermometers?

## CHALKBOARD ILLUSTRATIONS

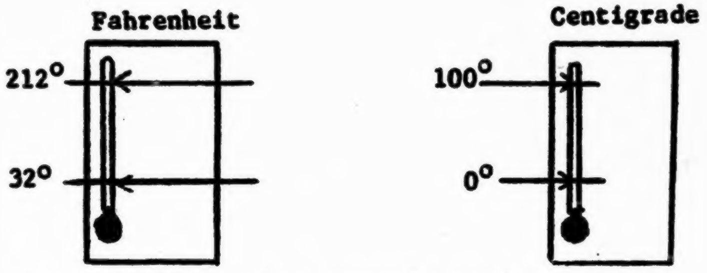


Fig. 1 Two scales commonly used to measure temperature.

Discussion: Help pupils to identify different kinds of thermometers used in their homes. Some pupils may be able to bring thermometers to class, e.g. fever thermometers, cooking thermometers, Fahrenheit and Centigrade thermometers. Pupils should realize that thermostats in homes, schools, and other buildings, use the bimetallic principle to control the temperature of rooms in the building. The Fahrenheit scale is commonly used in the United States, but engineers and scientists prefer the Centigrade scale.

Activities: Fill a bottle with water and add some food coloring to it. Place the tubing into the bottle. Heat the water on a hot plate and note the change in the level of water in the tubing. Cool the water and note the change. Mark the different positions of water in the tubing by having a pupil tie a colored string at the different water levels. Repeat this activity with a thermometer in place of the bottle. Place thermometer in boiling water and later in ice water to note these two readings on thermometer (C,F).

Have one or more pupils hold the tube of alcohol in his hand and describe what happens to the colored alcohol in the tube. Ben Franklin Thermometer

Heat the bimetallic strip with the hot plate and note the change in shape of the rod.

Results Expected: The water will expand and contract as heat is added or removed. This change can be observed by movement of the column of colored water in the tubing. Water is not useful in thermometers because it becomes a solid at 0°C and because it expands when it approachas this freezing point.

Since room temperature is about 70°F and body temperature is about 98°F, the temperature of the pupil's hand will cause the alcohol to expand sharply and move away from the heat. Cooling is accomplished by removing the hand.

The bimetallic strip bends because the two metals have different rates of expansion. Since they are locked together both strips are bent.

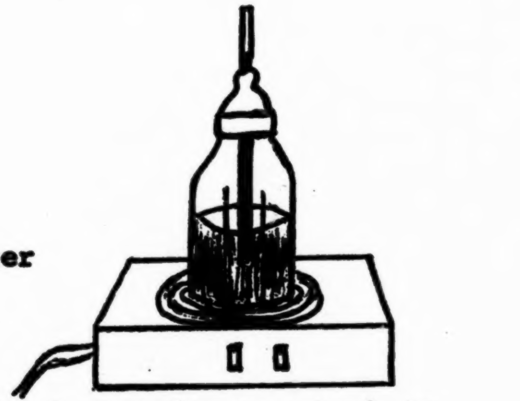


Fig. 2 Heated water expands in tube.

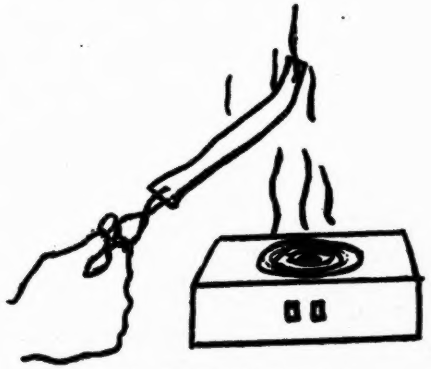


Fig. 3 Heated metal expands.

**TENTH DAY - SHOW FILMSTRIP #2, - "HOW HEAT CAUSES EXPANSION" (JAM HANDY, DETROIT, MICH.) - HAVE CAPTIONS READ ALOUD IN CLASS**

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## ELEVENTH DAY -- GENERALIZATIONS

1. It is natural for heat to travel from a hot region to a cooler region.
2. Although heat energy may change its form, it is never lost in moving from one place or form to another.
3. In conduction, heat energy is transferred from one molecule to another.
4. Heat travels easily through good conductors of heat.

## CLASS ACTIVITIES

**Reading!** Read pp. 26-28 silently and aloud.

**New Words:** conduction, transfer

**Materials:** candle, Pyrex dish, matches water, soldering iron, metal strip

Pupil Questions:
1. How does the heat travel along metal strip?
2. Where has heat from soldering iron gone?

**Discussion:** Help pupils to recognize that the heat energy is flowing from a hot region (hot wire in plate) to a cooler region (glass, water, air). This flow of heat is conducted (passed along) by the molecules in these materials. Pupils should realize that this heat energy has merely been transferred and not lost.

As the molecules in the metal strip receive more heat energy from the soldering iron, they pass this energy along to other molecules in the metal strip and to the molecules in the wax.

**Activities:** Plug hot plate cord into outlet and place Pyrex dish of water on plate when wire begins to glow red. Ask pupils to explain where heat energy starts and which objects receive this energy.

Place metal strip onto soldering iron. Light candle and drip rows of red wax onto the strip (note change of state from solid candle to liquid wax and back to solid wax strips) as in Fig. 2. Ask pupils to guess what will happen when soldering iron is plugged into wall outlet. Help them to identify source of heat (iron), direction of travel of heat (onto strip), and recipients of heat (strip, air, wax, soldering iron holder). Encourage pupils to recognize that the heat energy has changed its form (heat is received by air, metal, wax, etc.), but it has not been irretreviably lost.

**Results Expected?** Heat from hot plate will transfer energy to Pyrex dish and to water until water boils. Heat from soldering iron will travel along strip. This can be seen as the rows of wax melt and drop from the metal strip. The wax strip closest to the heat source (soldering iron) will drop first and others will follow.

## CHALKBOARD ILLUSTRATIONS

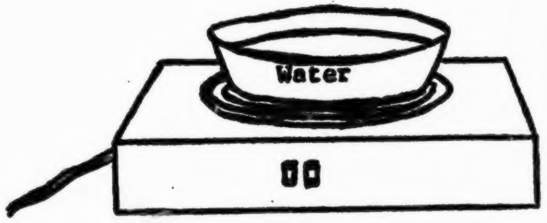

Fig. 1 Heat from hot plate wires is conducted to Pyrex glass, to water, to air.

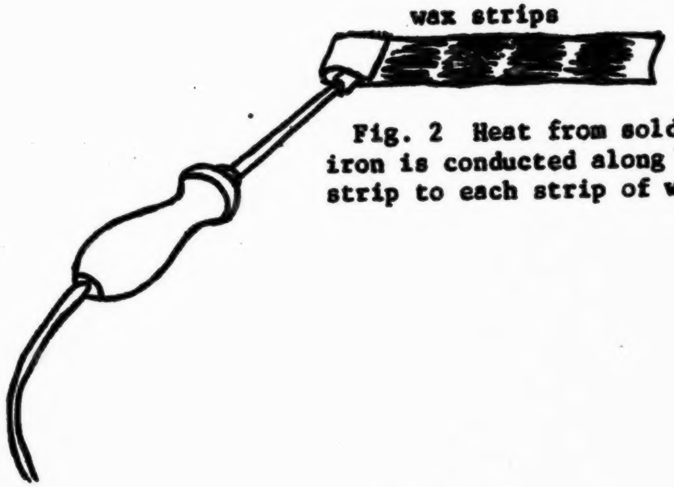

Fig. 2 Heat from soldering iron is conducted along metal strip to each strip of wax.

## TWELFTH DAY -- GENERALIZATIONS

1. Metals conduct heat better than liquids or gases.
2. There are some materials through which heat does not travel easily and they are called poor conductors of heat or insulators.
3. Paper, water, air and glass are often used as insulators.
4. Poor conductors can be used to keep things hot or cold.
5. An insulator keeps most of the heat from moving into a cooler region.

## CLASS ACTIVITIES

**Reading**: Read pp. 26-28 silently and aloud.

**New Words**: insulator

**Materials**: water, candle, hot plate, Pyrex bowls, metals, non-conductors, conductors, matches.

**Pupils Questions**:
1. How do we use poor conductors?
2. Why did only one paper cup feel hot?

**Discussion**: Pupils should realize that good conductors have their practical uses in making cooking utensils, stoves, irons and similar appliances. However, poor conductors are also important. The latter are particularly useful in insulating buildings to keep the heat inside in winter and the cold outside. Poor conductors insulate our refrigerators, our clothes insulate our bodies in the winter, and even our earth is insulated by that very poor conductor of heat -- air. Discuss with the pupils other insulating materials they've seen at home or in stores.

**Activities**: Place different objects into boiling water for about two minutes. Roughly classify each object as poor conductor or as good conductor of heat according to "touch."

Pour some hot water into the two paper cups included in the kit. Ask pupils to explain why one cup feels hot and the other cup doesn't.

**Results Expected**: Table 1 shows major classes of good conductors and poor conductors of heat. Because one paper cup has many air spaces and the other cup does not, heat will be transferred readily through one paper cup and heat is barely noticeable for the other cup.

## CHALKBOARD ILLUSTRATIONS

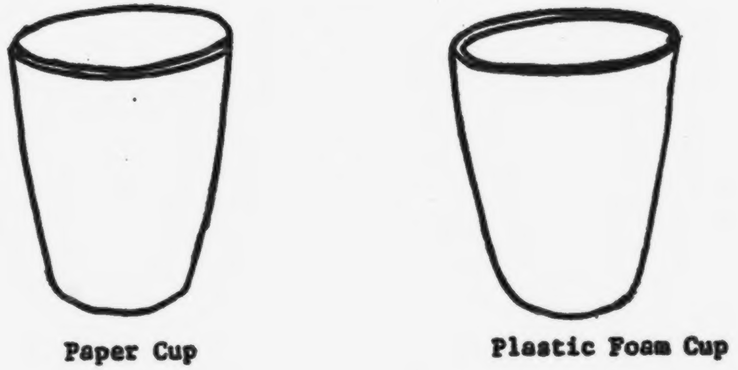

Fig. 1 Plastic cup has air spaces for insulation

Table 1 -- Conductors of Heat

| Good Conductors | Poor Conductors |
|---|---|
| silver | air |
| iron | glass |
| aluminum | paper |
| copper | wood |
| most metals | water |
| | asbestos |

## THIRTEENTH AND FOURTEENTH DAYS -- GENERALIZATIONS

1. Convection is the transfer of heat energy of molecules in moving currents of fluids.
2. Convection currents in fluids are created when lighter parts of a fluid are forced upward by cooler and heavier parts which gravity forces downwards.
3. Convection currents in air occur when warm air is pushed upwards by colder, heavier air which has been pulled downward by gravity.
4. Heat is transfeрred by molecules in the convection current to other molecules in the fluid.
5. Atmospheric circulation and ordinary ventilation depend upon convection currents.

## CLASS ACTIVITIES

Reading: Read pp. 29-30 silently and aloud. Read pp. 34-41 as time permits.

New Words: convection, gravity, atmosphere, circulation

Materials: water, metal spiral, candle, glass tube, coloring material

Pupil Questions:
1. Why does the warm air go upwards?
2. What's the difference between conduction and convection?

## CHALKBOARD ILLUSTRATIONS

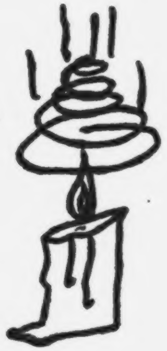

Fig. 1 Metal spiral turns clockwise as hot air rises from candle.

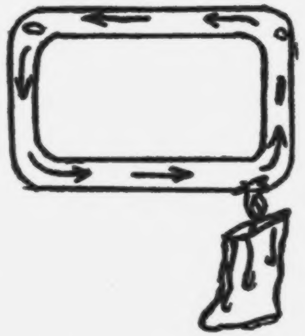

Fig. 2 Candle heats water and sets up convection current in tube of water.

Discussion: In convection, the molecules of warm fluid are literally moved and their places are occupied by the molecules of the cool fluid. In one sense the colored material may help to establish the concept that it is not merely energy which is being transferred, but the molecules of matter are also being transferred. This transfer brings excited, high energy molecules into contact with cold, lower energy molecules.

Pupils should recognize that convection currents occur in the earth's atmosphere and produce winds. Ventilation of rooms in buildings often depend upon gravity to pull the cold, heavy air down to the furnace to be heated.

Activities: Light a candle and hold the metal spiral over the flame (Fig. 1). Ask pupils to explain why the spiral turns. Note that it turns in a clockwise direction. Move the spiral away from the heat and note that the turning stops. Blow downward onto the top of the spiral and note which direction the spiral turns.

Fill the rectangular tube with water and place the colored material inside the tube. Call attention to where the colored material is inside the tube. Heat one side of the tube (Fig. 2) and ask pupils to explain what they observe.

Results Expected: The air directly above the candle is heated and expands. Cooler air pushes the hot air upwards. As it is pushed upwards, the warm air encounters the spiral and exerts the slight force which is necessary to turn the spiral in clockwise direction. When the flame is extinguished, the air above the candle is about the same temperature as the surrounding air. Therefore, it is not pushed upward and does not move the spiral. If you blow downward onto the top of spiral, the force of your breath turns the spiral in counterclockwise direction.

When the water is about the same temperature, there is no difference in the weight of the water. When the heat is applied to one side of the tube, that water is heated and is forced upward by the inflow of cooler (heavier) water. This cycle continues and can be observed by watching the colored material flow in a cycle.

I-47

**FIFTEENTH DAY -- GENERALIZATIONS**

1. Radiant energy is emitted by almost all materials.
2. Although most radiant energy cannot be seen, it travels like rays of light.
3. Energy from the sun travels to earth by radiation.
4. When an object absorbs radiant energy, its molecules move faster and increase its heat energy.
5. Mirrors and shinning surfaces reflect radiant energy.
6. Dark objects absorb radiant energy.

**CLASS ACTIVITIES**

**Reading**: Read pp. 31-33 silently and aloud. Read pp. 42-47 as time permits.

**New Words**: Radiation, radiant energy, absorb, rays

**Materials**: filmstrip projector, black and white papers, two thermometers

**Pupil Questions**:
1. Why is radiation important?
2. Why did the pupil's hand feel warm when the light struck it?

**CHALKBOARD ILLUSTRATIONS**

**Discussion**: Help pupils to realize that radiation is the means which brings to earth all of the energy which we receive from the sun. Without this form of energy, life would cease to exist. The visible light rays from the projector are only a small portion of the radiant energy which the earth receives.

Pupils should recognize that although most radiant energy cannot be "seen," it has been found to be very similar to visible light. That is, it travels very rapidly in straight lines; and it may be feflected by mirrors, bent by lenses, or absorbed by objects.

**Activities**: Have a pupil stand close to the filmstrip projector. Direct the beam of light from the projector onto his hand. Ask him to explain what he felt when the light was turned on. Turn off the projector and ask the pupil if his hand was cooler. Encourage pupils to explain the heating by light.

Place a black paper over one thermometer and a white paper over a second thermometer. Direct the light from the projector onto each paper for the same time and at the same distance. Encourage pupils to estimate the temperatures after five minutes of light.

**Results Expected**: As soon as the light strikes his hand, the pupil will feel a warmth. This is caused by the radiant energy (light) which is absorbed by the hand and "sensed" as heat energy. When the light is turned off, the warm feeling will also end.

Black or colored materials will absorb radiant energy, while polished surfaces or mirrors reflect this energy. Therefore the thermometer under the black paper will indicate a higher temperature than the thermometer under the white paper.

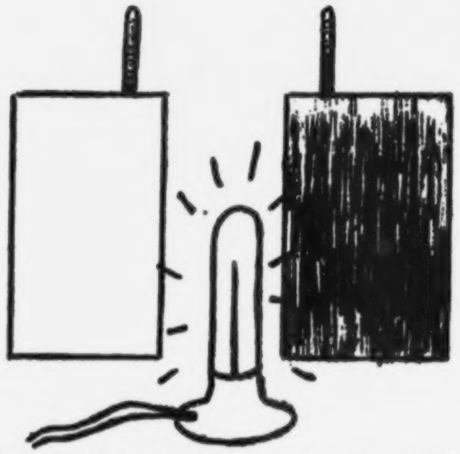

Fig. 1 White and black papers absorb different amounts of heat from lamp.

SIXTEENTH DAY - SHOW FILMSTRIP #3, - "HOW HEAT TRAVELS" (JAM HANDY, DETROIT, MICH.) - HAVE CAPTIONS READ ALOUD IN CLASS

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## MATERIALS INCLUDED IN KIT FOR HEAT UNIT

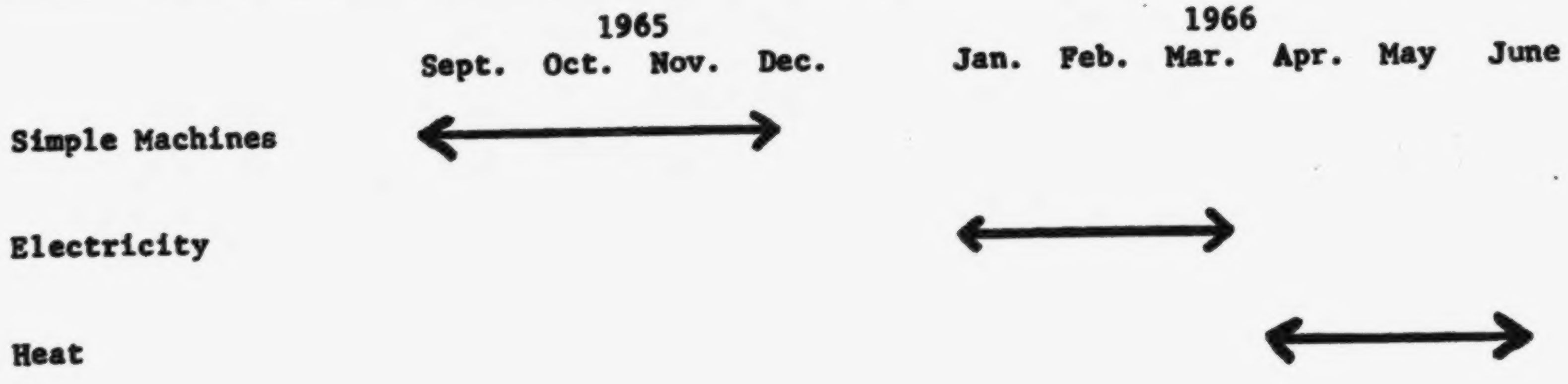
balloons
glass tubes
baby bottle
food coloring
hot plate
bottle cap
bottle of alcohol
jar (for water)
cotton swabs
candles
Pyrex dish
matches

soldering iron
metal strip
metal-shot and filings
metal spiral
black and white papers
4 thermometers
3 filmstrips
nichrome wire
light bulb and socket
2 plastic bags
jar of moth balls
jar of ammonia

3 aluminum pans
paraffin blocks
tongs
jar of lead shot
jar of steel shot
convection rectangle
Franklin Palm Glass
2 cups (paper, styrofoam)
immersion heater
asbestos paper
compound bar

35 textbooks: Theodore W. Munch, What Is Heat, Benefic Press, Chicago, 1960, 48 pages.

## SCHEDULE OF INSTRUCTION FOR UNITS



## Appendix J-1
## INSTRUCTIONS USED TO GUIDE TEST ADMINISTRATORS

### A. Organization of Materials Before Testing:

1. Have about 50 pencils sharpened and ready for pupils.

2. Be sure that you have test booklets, answer sheets for each class of pupils who are to be tested.

3. Be sure that you know where the school is located, the specific classes to be tested, the time you are expected, the time when testing is to begin and end.

4. When you arrive at the school, go directly to the office to inform the principal or assistant principal that you've arrived.

5. When you arrive in the classroom, sort your answer sheets and booklets into convenient piles so that they may be readily distributed.

6. Hang the "Testing -- Do Not Disturb" sign on the door outside of the classroom.

### B. Administering the Test to Pupils:

1. Introduce yourself to the class: "I am Mr.________, from Wayne State University. We're trying to discover how much boys and girls at _________school know about science. Today, I'm going to give you a test. It will be hard; so we'll have to work together. By raising your hands, show me how many I can count upon for help. Fine!"

2. Have pupils clear the tops of their desks. Quickly distribute pencils and answer sheets. Have pupils print or write first and last name in appropriate place.

3. Set up sample marking space at chalkboard (see below).

1. $\boxed{1}$ $\boxed{2}$ $\boxed{3}$ $\boxed{4}$ $\boxed{5}$

4. Distribute booklets to each table or row. Wait until it is quiet and you have pupils' attention. Then read the directions precisely as they are written. Work the sample problem and mark the correct answer on chalkboard. If there are one or two questions answer them briefly and proceed immediately to the first item on the test.

5. Read each question and its possible answers in a loud firm voice. As you pronounce the answers, do not give special inflection or emphasis to any answer. As a matter of fact, it is preferred that you not know which answer is the best answer. If pupils ask you questions about meanings of terms, do not give any interpretation.

6. Move about the classroom occasionally. Watch for pupils who may be marking their answer sheet incorrectly. If this occurs, simply initial the student's paper and tell him to proceed with the next question.

7. Throughout the testing, try to maintain a firm, business-like demeanor. Use gestures, facial expressions, soundless whispers in dealing with the pupils. If a serious disturbance seems imminent, send the pupil to the principal's office and settle the matter afterwards. If you notice someone copying the answers of a neighbor, stare at him or walk directly to his side. If this copying persists, simply put your initials on his paper. However, allow him to continue taking the test without disturbing the other students.

8. When the test has been completed, collect the pencils, test booklets, answer sheets, and the test sign. Unless you must hurry to test another class, skim through the answer sheets to be sure that each one has a name.

9. The regualar classroom teacher should be nearby. If not send one child to the office to inform her that the testing is completed.

10. If there were any irregularities, make a note of these on the envelope containing the class's answer sheets.

J-3

Table 215 SCHEDULE OF TESTS ADMINISTERED DURING EXPERIMENTAL STUDY

| Name of Test | 1965 | | | | 1966 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sept. | Oct. | Nov. | Dec. | Jan. | Feb. | Mar. | Apr. | May | June | Sept. | Oct. | Nov. |
| Machines | | | | | | | | | | | | | |
| Pre-T. (M1) | ↔ | | | | | | | | | | | | |
| Post-T. (M2) | | | ↔ | ↔ | | | | | | | | | |
| Ret-T. (M3) | | | | | | ↔ | ↔ | | | | | | |
| Electricity | | | | | | | | | | | | | |
| Pre-T. (E1) | | | | | ↔ | | | | | | | | |
| Post-T. (E2) | | | | | | ↔ | ↔ | | | | | | |
| Ret-T. (E3) | | | | | | | | | | ↔ | | | |
| Heat | | | | | | | | | | | | | |
| Pre-T. (H1) | | | | | | | ↔ | ↔ | | | | | |
| Post-T. (H2) | | | | | | | | | | ↔ | | | |
| Ret-T. (H3) | | | | | | | | | | | ↔ | ↔ | ↔ |
| I.Q. Test | | ↔ | ↔ | | | | | | | | | | |
| Science Ach. Test | | | | ↔ | | | | | | | | | |
| Reading Test | ↔ | | | | | | | | | | | | |

J-4

## INSTRUCTIONS FOR PRE-UNIT TEST ON MACHINES

In the following test you will be asked questions about machines. After each question there will be four answers. You are to choose the best answer and mark the number of that answer on your answer sheet. Do not make any marks on the booklet. Make all marks on the answer sheet.

You are not expected to know all of the answers to these questions about machines. Don't feel bad if you don't know some of the correct answers. The purpose of this test is to find out how much boys and girls in the elementary schools know about machines before they have studied it in school. DO NOT GUESS WILDLY. If you do not know the answer to a question, skip over that question and go on to the next.

You will not know all of the words in the test. Your teacher will read the questions and possible answers with you. This is done to help you with some of the hard words. Wait until the questions and answers have been read aloud. Then select the correct answer, if you know it. If you do not know the correct answer, you may darken the space of answer #5.

Let's look at this sample question:

1. Which of the following is not a planet of our Sun?

1. Earth    2. Mars    3. Saturn    4. Moon

Which is the correct answer: Yes, ________ is the right answer, and so you would darken space number________ on your answer sheet.

If you wish to change an answer, erase the first mark carefully. Then make your new choice by darkening the space of the number of your new choice.

As soon as everyone is ready, we will begin. There are ________ pages to this test.

Are there any questions?

1. Which of the following will usually have mechanical energy ready for use?

   1. Earth 2. Automobile 3. Sun 4. Wood

2. When a boy runs a race what happens to the energy he used?

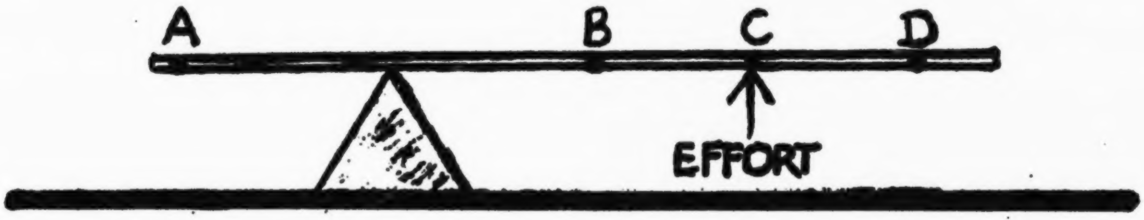
   1. He still has it to use again.
   2. It's all used up.
   3. He didn't use any energy.
   4. Something else has it now.

3. A scientist would say that no work is done when:

   1. Water runs into a sink.
   2. A boy throws his ball.
   3. A man is leaning against a tree.
   4. All three of these happen.

4. A scientist would say that no work was done with a pencil that is

   1. resting on a desk.
   2. used to scribble on paper.
   3. thrown at a wall.
   4. anyone of these above.

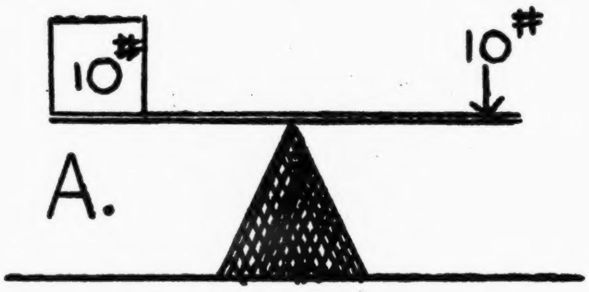


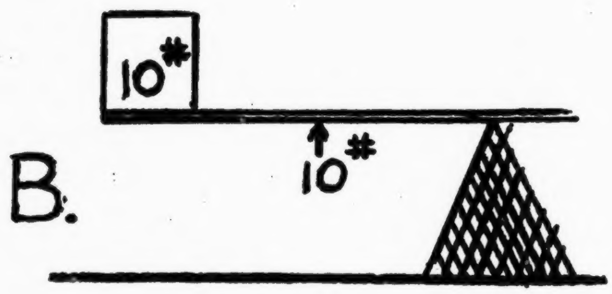
5. Look at the picture above. If this is a second-class lever, where is the load located?

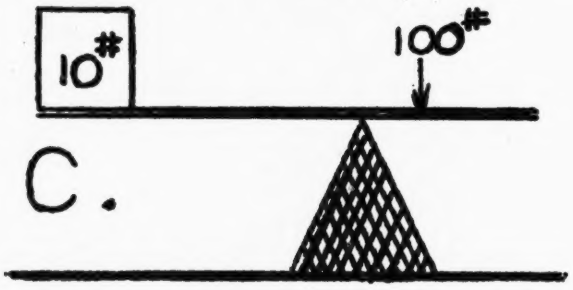
   1. A 2. B 3. C 4. D

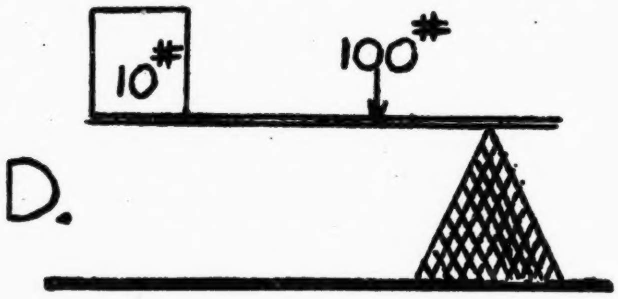
6. Look at the picture above. If this was a third-class lever, where would the load be located?

   1. A 2. B 3. C 4. D









7. Look at the pictures (A,B,C,D) above. In which picture will the #10 load be lifted?

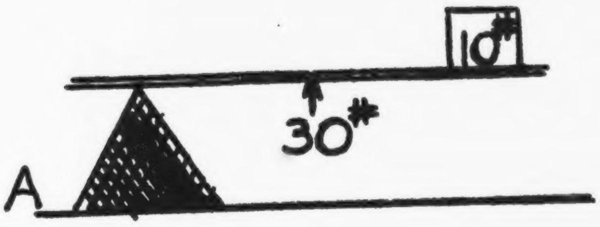
1. A    2. B    3. C    4. D

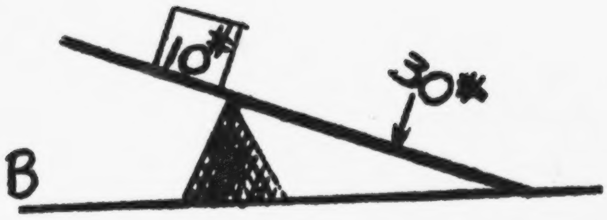
8. Look at the pictures (A,B,C,D) above. In which picture will no work be done?

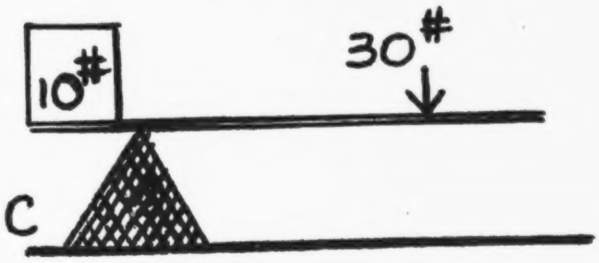
1. A    2. B    3. C    4. D

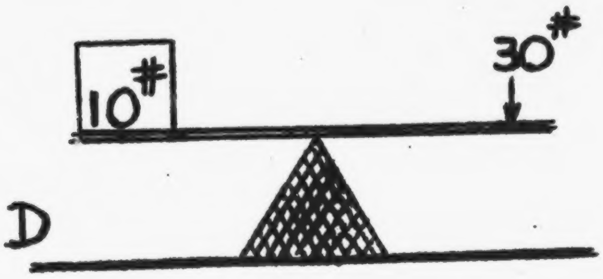
9. Look at picture "D" above. Which of the following is true for that picture?

1. Both load and force travel same distance.
2. Both load and force travel at same speed.
3. 10# travels farther than 100#.
4. 100# travels farther than 10#.









10. Look at the pictures (A,B,C,D) above. In which picture is the load arm longer than the 30# force arm?

1. A 2. B 3. C 4. D

11. Look at the pictures above. In which pictures is the force arm longer than the load arm?

1. A and B 2. B and C 3. C and D 4. B and D

12. Look at the pictures above. In which picture will the lever not move?

1. A 2. B 3. C 4. D

13. Look at the pictures above. In which pictures will the 10# load and the 30# force travel at the same speed?

1. A 2. B 3. C 4.D

14. Look at the pictures above. In which picture will the 30# force travel farther than the 10# load?

1. A 2. B 3. C 4. D

15. Look at the pictures above. In which picture will the 10# load travel faster than the 30# effort force?

1. A 2. B 3. C 4. D

16. Look at the pictures above. In which picture will the load and the force travel the same distance?

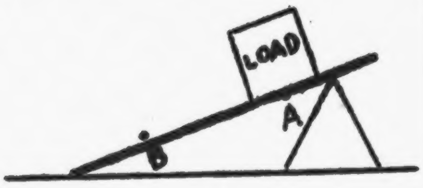
1. A 2. B 3. C 4. D

17. Which of the following is not usually used as a lever?

1. Shovel
2. Hand saw
3. Crowbar
4. Hammer

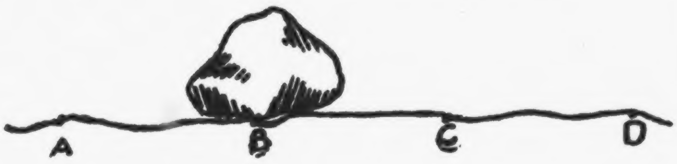
18. If the lifting force is moved from A to B, which of the following is true?

1. Load is easier to move.
2. Load is harder to move.
3. Force moves at same speed at B or A.
4. Load moves faster.



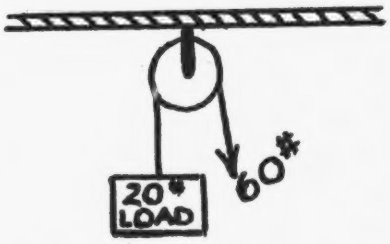
19. The rock is to be lifted with a lever. Where should the fulcrum be placed so that the smallest force will be used to lift it?

1. A or B
2. B or C
3. A or C
4. C or D

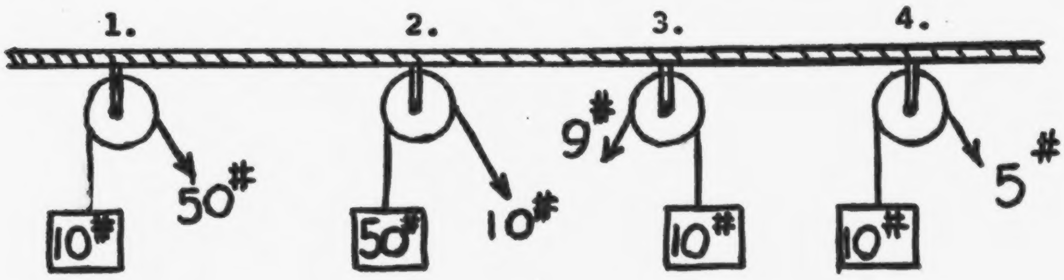


20. Consider the picture at the right. Which of the following is correct?

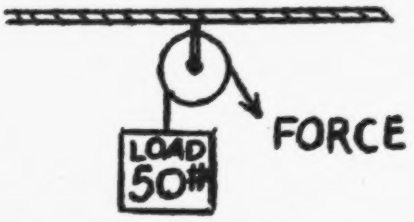
1. Load and force balance evenly.
2. 60# force moves faster than the load.
3. Load travels farther than force.
4. Load travels same distance as force.



21. With which pulley will the load be moved upward?

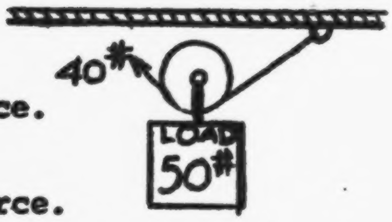


22. In order to make this pulley work, how much force must be used to raise the load?



1. 25#
2. 50#
3. More than 50#
4. Less than 50#

23. Consider the picture at the right
Which of the following is correct?



1. Load travels faster than effort force.
2. Force travels farther than load.
3. Load does not move.
4. Load travels farther than effort force.

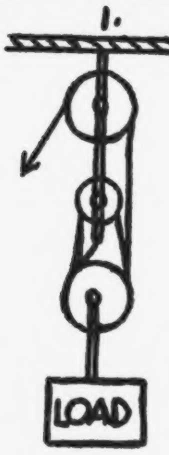
24. Which of the following does not use a pulley?

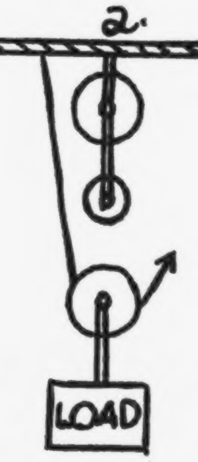
1. Flag pole
2. Roller skate
3. Steam shovel
4. Elevator

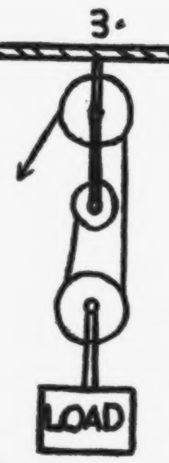
25. If a load is raised 2 feet by a movable pulley, the lifting force will travel about:

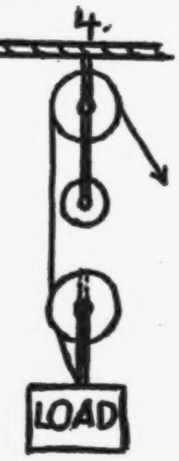
1. 1 foot
2. 2 feet
3. 3 feet
4. 4 feet

26. Which of the following will lift the greatest weight with the least effort?



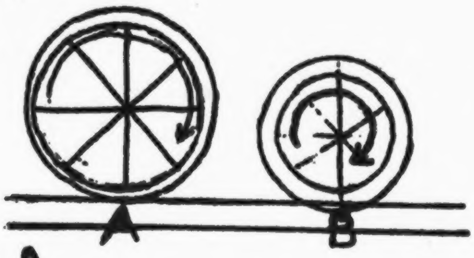






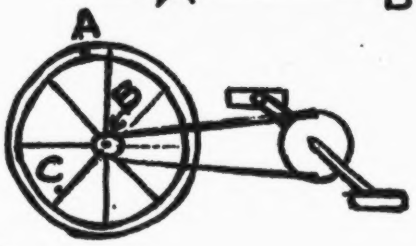
27. If wheels A and B make one complete turn on the sidewalk, then___

   1. Wheel A goes the same distance as wheel B
   2. Wheel B travels faster than wheel A
   3. Wheel A goes farther than wheel B
   4. Wheel B goes farther than wheel A



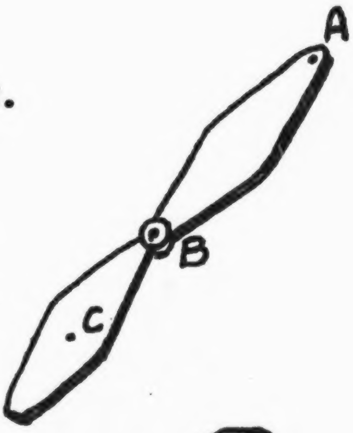
28. A bicycle wheel is shown at the right with points A,B, C. When it turns:

   1. A travels farthest
   2. B travels farthest
   3. C travels farthest
   4. All points travel same distance.



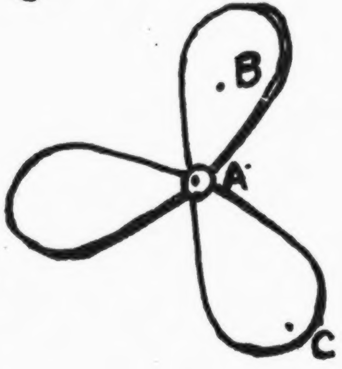
29. The airplane propeller has points A,B,C. When it turns:

   1. A travels farthest and fastest.
   2. B travels farthest and fastest.
   3. C travels farthest and fastest.
   4. All points travel at same speed.

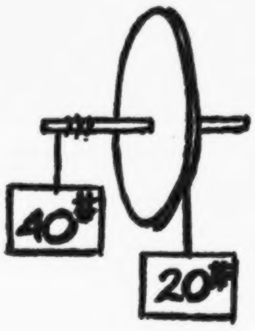


30. The front of an electric fan is shown at the right with points A,B,C. When it turns:

   1. A travels fastest
   2. B travels fastest
   3. C travels fastest
   4. All points travel at same speed.

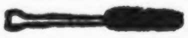
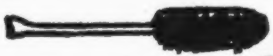
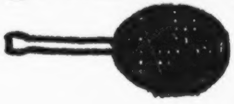


31. With weights hanging from ropes as shown, which of the following will happen?

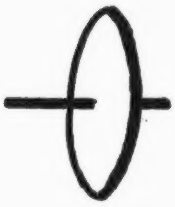


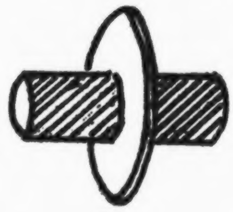
1. 40# weight goes down.
2. 20# weight goes down.
3. Both weights go down.
4. 40# weight balances 20# weight.

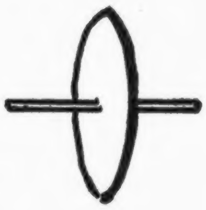
32. Which screwdriver will need the least effort to turn the same screw?

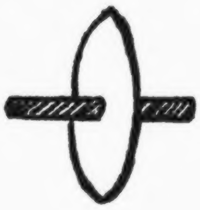
1. 
2. 
3.
4. 

33. In which picture is the axle arm at its' largest?

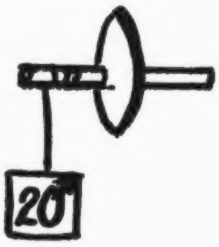

1.


2.

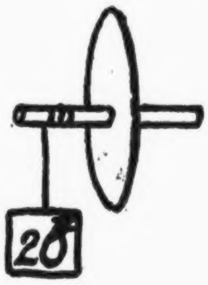

3.


4.

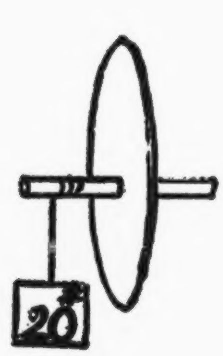
34. Which of the following wheels will require the least effort force to move the 20# weight?



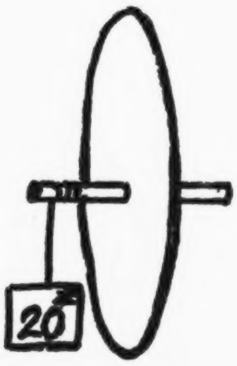
1.



2.

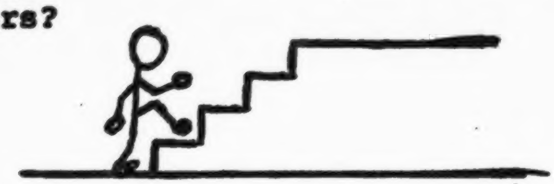


3.



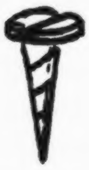
4.

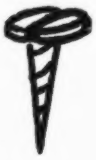
35. What simple machine is illustrated by the stickman going up the stairs?

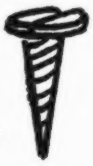


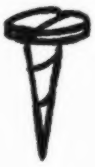
1. Inclined plane
2. Screw
3. Lever
4. Wedge

36. Which of the following screws would be easiest to use in wood?

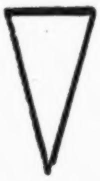
1)


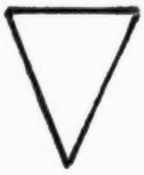
2)


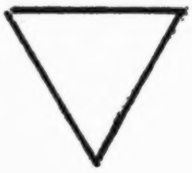
3)


4)


37. Which of the following wedges would be easiest to use in wood?

1.


2.


3.


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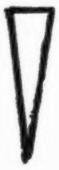
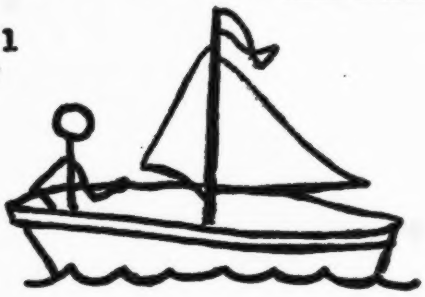


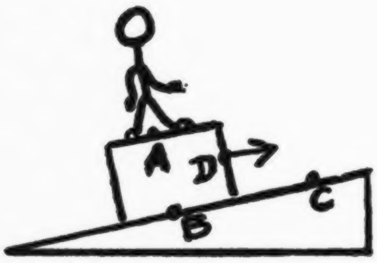
38. As the stick man sits in his boat, where does friction not exist?

1. Between the stick man and the sail
2. Between the stick man and the air
3. Between the sail and the wind
4. Between the boat and the water



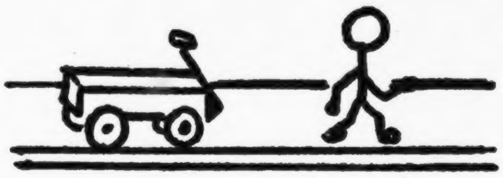
39. As the box with the stick man is moved, where will the friction be greatest?

1. A
2. B
3. C
4. D



40. As the wagon rolls along the sidewalk, where does friction not exist?

1. Between air and stick man
2. Between air and wagon
3. Between wagon and sidewalk
4. Between stick man and wagon



41. If you quickly rub your hands together, they become warm. What causes this?

1. Energy from one hand is given to the other hand
2. Mechanical energy between your hands
3. Friction between your hands
4. Moving your hands

42. Which of the following has some friction?

1. Fans
2. Roller skates
3. Airplanes
4. All three of the above.

43. Which of the following is an example of sliding friction?

1. Roller skating on sidewalk
2. Singing in wind
3. Writing on chalkboard
4. Swimming in lake

44. Which of the following is not an example of fluid friction?

1. Swimming
2. Mississippi River
3. Thunderstorm
4. Skiing

45. Which of the following is an example of rolling friction?

1. Bike moving on sidewalk
2. Writing on chalkboard
3. Running to automobile
4. Walking on sidewalk

46. What type of friction is important to objects traveling through air?

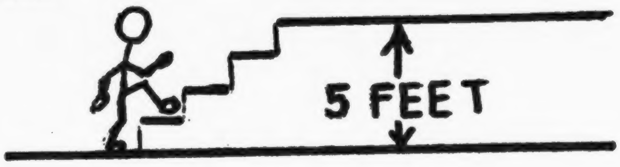
1. Grinding
2. Fluid
3. Rolling
4. Sliding

47. What kind of friction is important to the use of automobiles, roller skates and bicycles?

1. Sliding
2. Rolling
3. Grinding
4. Fluid

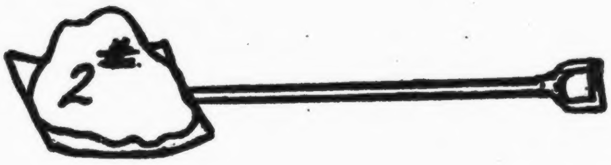
48. How much work is done when the 100# stick man runs up the four steps?

1. 104 units of work
2. 400 units of work
3. 120 units of work
4. 500 units of work



49. If the snow is lifted 6 feet, how much work has been done?

1. 8 units of work
2. 4 units of work
3. 12 units of work
4. 3 units of work



50. Three boys jumped off a 6-foot porch. How much work was done ?

1. 3 units of work.
2. 18 units of work was done.
3. More information is needed.
4. No work was done.

### Table 216 PREFERRED ANSWERS TO QUESTIONS ON SIMPLE MACHINES TEST

| Test Item | Preferred Answer | Test Item | Preferred Answer |
|---|---|---|---|
| 1 | 2 | 26 | 1 |
| 2 | 4 | 27 | 3 |
| 3 | 3 | 28 | 1 |
| 4 | 1 | 29 | 1 |
| 5 | 2 | 30 | 3 |
| 6 | 4 | 31 | 2 |
| 7 | 3 | 32 | 4 |
| 8 | 1 | 33 | 2 |
| 9 | 3 | 34 | 4 |
| 10 | 1 | 35 | 1 |
| 11 | 2 | 36 | 3 |
| 12 | 2 | 37 | 4 |
| 13 | 4 | 38 | 1 |
| 14 | 3 | 39 | 2 |
| 15 | 1 | 40 | 4 |
| 16 | 4 | 41 | 3 |
| 17 | 2 | 42 | 4 |
| 18 | 1 | 43 | 3 |
| 19 | 3 | 44 | 4 |
| 20 | 4 | 45 | 1 |
| 21 | 1 | 46 | 2 |
| 22 | 3 | 47 | 2 |
| 23 | 2 | 48 | 4 |
| 24 | 2 | 49 | 3 |
| 25 | 4 | 50 | 3 |

## INSTRUCTIONS FOR POST-UNIT TEST ON ELECTRICITY

In the following test you will be asked questions about electricity. After each question there will be four answers. You are to choose the best answer and mark the number of that answer on your answer sheet. Do not make any marks on the booklet. Make all marks on the answer sheet.

You are not expected to know all of the answers to these questions about electricity. Don't feel bad if you don't know some of the correct answers. The purpose of this test is to find out how much boys and girls in the elementary schools know about electricity after they have studied it in school. DO NOT GUESS WILDLY. If you do not know the answer to a question, skip over that question and go on to the next one.

You will not know all of the words in the test. Your teacher will read the questions and possible answers with you. This is done to help you with some of the hard words. Wait until the questions and answers have been read. Then select the correct answer, if you know it. If you do not know the correct answer, you may darken the space under answer #5.

Let's look at this sample question:

1. Which of the following planets is farthest from the Sun?

1. Earth    2. Mars    3. Saturn    4. Pluto

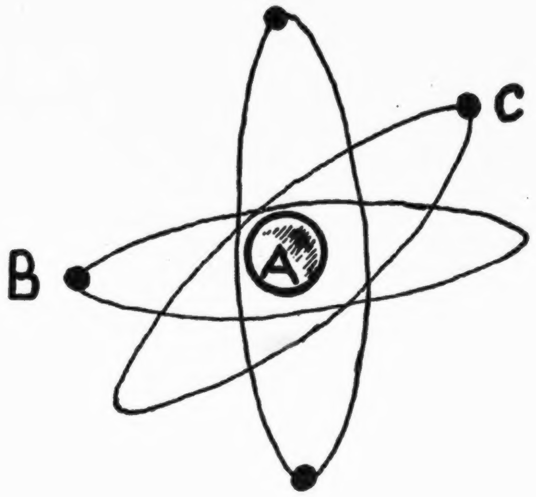
Which is the correct answer: Yes, _______ is the right answer, and so you would darken the space on your answer sheet under__________.

If you wish to change an answer, erase the first mark carefully. Then make your new choice by darkening the space under the number of your new choice.

As soon as everyone is ready, we will begin. There are ______ pages to this test.

Are there any questions?

J-17



1. The picture (above) shows what an atom may look like. Where is the greatest negative charge?

   1) at A 2) between A and C 3) at B or C 4) between A and B

2. In the picture above, what is the name of the object at "B"?

   1) proton 2) molecule 3) nucleus 4) electron

3. In the picture above what is the name given to the rings around "A"?

   1) nucleus circuits
   2) electron paths
   3) molecule paths
   4) none of these answers

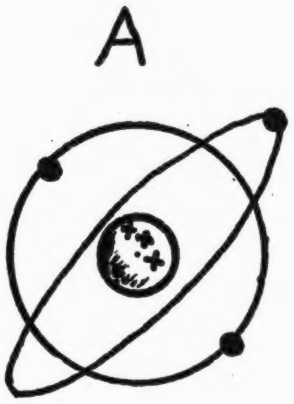
4. In the picture above, where is the greatest positive charge?

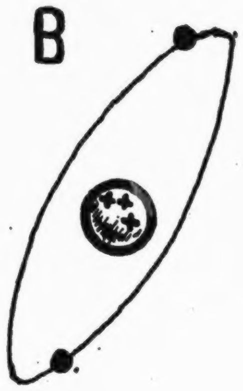
   1) at A 2) at B 3) at C 4) at B or C

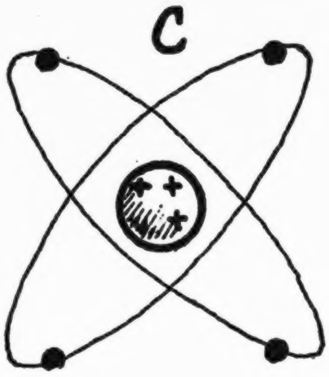
5. In the picture above, what is the name of "A"?

   1) electron 2) molecule 3) nucleus 4) negative charge

J-18







6. If the pictures above show three atoms, which atom has a neutral charge?

   1) A   2) B   3) C   4) all have same neutral charge

7. If the pictures above show three atoms, which atoms will repel one another?

   1) B and C   2) A and C   3) B and A   4) none repel

8. In the picture of three atoms shown above, which atom has the greatest negative charge?

   1) A   2) B   3) C   4) all have same negative charge

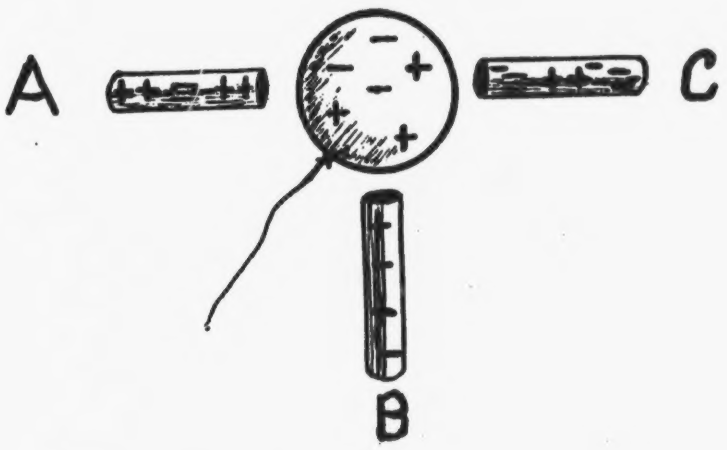
9. In the pictures above, which atom has the greatest positive charge?

   1) A   2) B   3) C   4) all have same positive charge

10. If the pictures above show three atoms, which atoms will attract one another?

    1) B and C   2) A and C   3) B and A   4) all attract each other

J-19



11. In the picture above there are 3 rods and a balloon. Which object is negatively charged?

1) the balloon 2) rod A 3) rod B 4) rod C

12. In the picture above, which object is positively charged?

1) the balloon 2) rod A 3) rod B 4) rod C

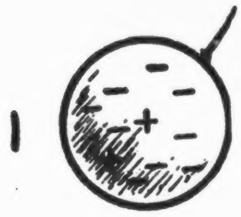
13. In the picture above, which object will try to capture electrons?

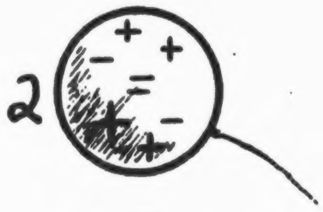
1) the balloon 2) rod A 3) rod B 4) rod C

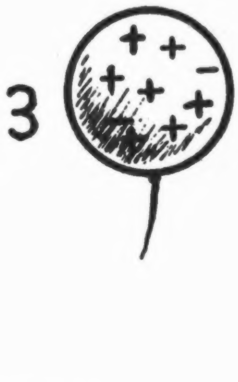
14. In the picture above, which of the rods will be attracted to the balloon?

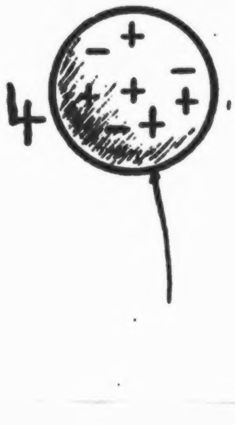
1) A and B 2) B and C 3) A and C 4) all of the rods

15. Which object below will try to release electrons?









16. What is the common way to make static electricity?

1) by rubbing
2) by electric motor
3) by rain
4) by electric light bulb

17. Where will static electricity usually be greatest?

1) in the nucleus
2) on the surface of a material
3) inside the material
4) on top of the nucleus

18. About how many atoms are contained in the box?

1) about 100     2) about 1000     3) about 1 million     4) more than 1 million.

19. An electric motor can be operated by energy from:

1) sunlight     2) waterfalls     3) burning candle     4) all of these

20. When electrons move along a wire, what is this called?

1) closed current
2) electric circuit
3) electric current
4) open circuit

21. Which of the following best describes electricity?

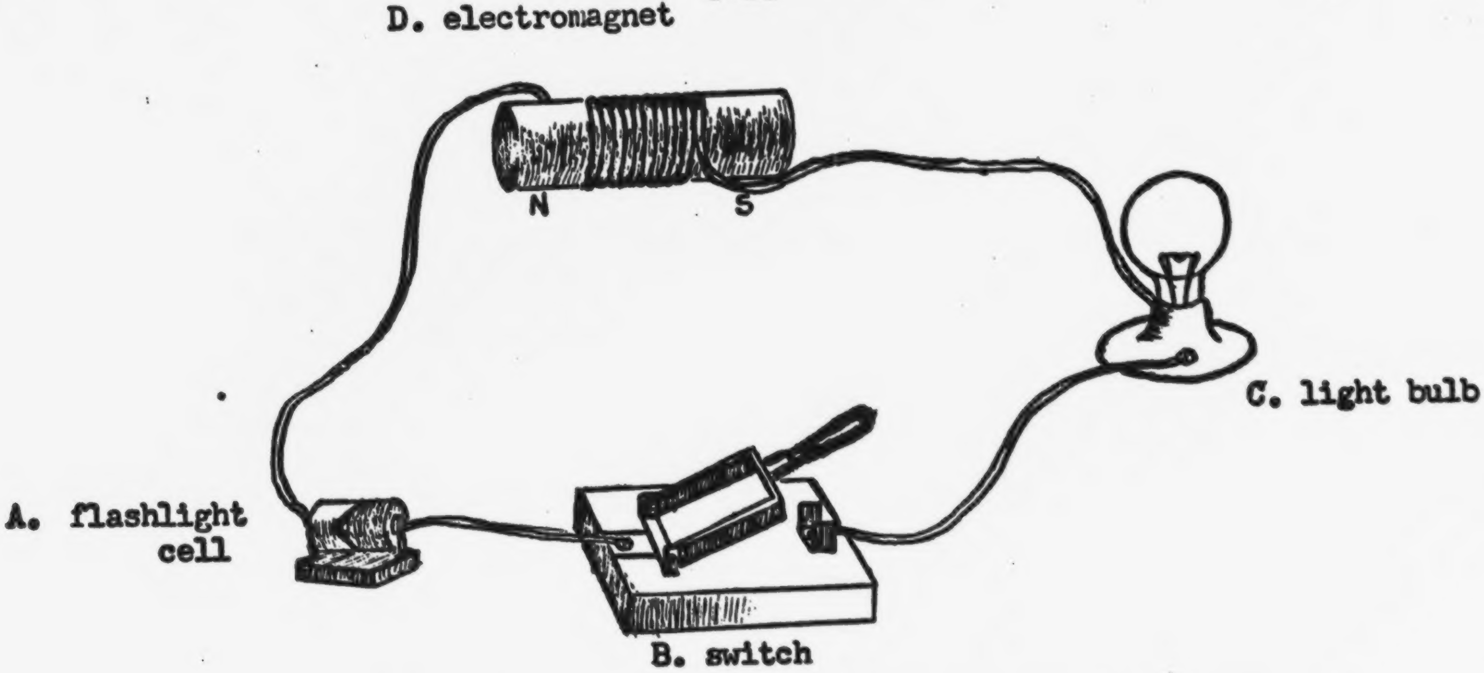
1) flowing atoms
2) flowing nucleus
3) flowing electrons
4) flowing molecules

22. Which of the following is at the center of the atom?

1) negative charge     2) nucleus     3) electron     4) molecule

23. Which of the following may be made by using electrical energy?

1) heat to cook food
2) light for a room
3) energy to move cars
4) all three of these



24. Consider the picture above. To make a closed circuit, where is a change needed (A,B,C,D)?

1) A 2) B 3) C 4) D

25. Look at the picture above. Which of the items (A,B,C,D) is the source of electricity?

1) A 2) B 3) C 4)D

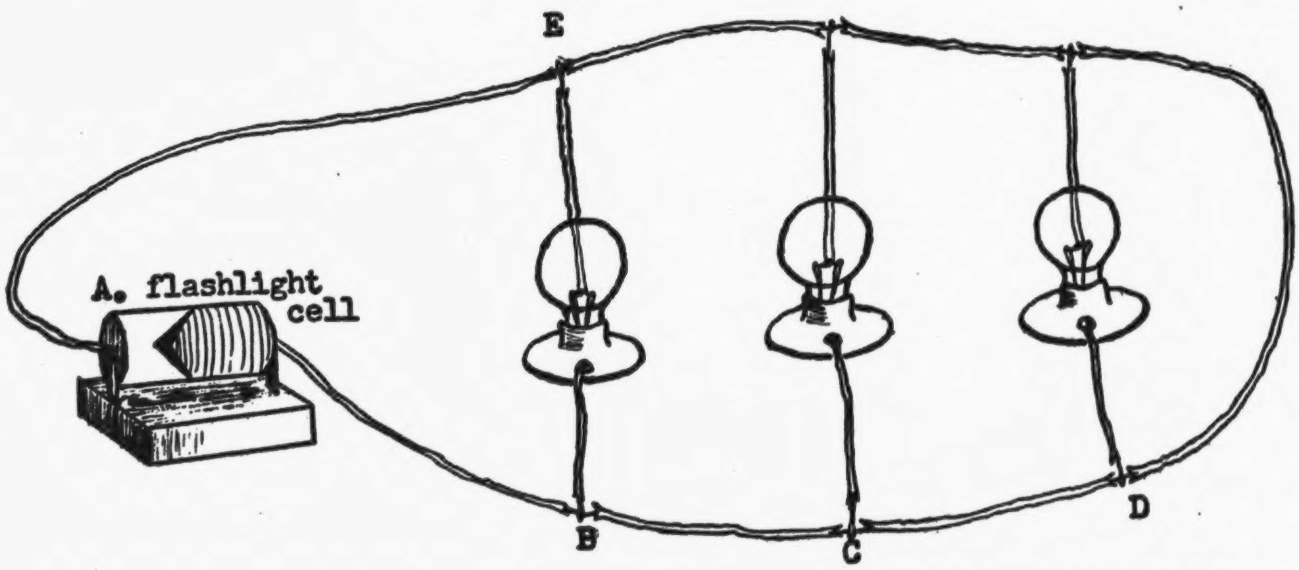
26. Look at the picture above. When the circuit is closed, which direction will the electricity move?

1) from light bulb to magnet
2) from flashlight cell to switch
3) from flashlight cell to electromagnet
4) from electromagnet to flashlight cell

27. Look at the picture above. If the circuit was closed what would be the best name for this arrangement?

1) parallel circuit
2) light bulb circuit
3) magnetic circuit
4) series circuit

J-22



28. In the picture above, what is the name for this arrangement of wires, flashlight cell, and lamps?

    1) switch circuit
    2) series circuit
    3) parallel circuit
    4) open circuit

29. Look at the picture above. Which of the following objects would usually have this arrangement of wiring?

    1) a house
    2) an auto
    3) christmas tree lights
    4) all of these

30. Look at the picture above. What is the name of the path from A to E to B and back to A again?

    1) switch circuit
    2) open circuit
    3) closed circuit
    4) atomic circuit

31. What is a chemical change?

    1) when two chemicals are mixed
    2) when something changes shape
    3) when something disappears
    4) when a new material is made

32. Which of the following will strongly resist the flow of electricity?

    1) cotton 2) metal 3) silver 4) all of these

33. What moves electrons through a conductor?

    1) pressure of excess atoms
    2) pressure of excess electrons
    3) pressure of excess energy
    4) loss of energy

34. An electric cell or battery uses a chemical change to make:
    1) an excess of energy
    2) a loss of molecules
    3) an excess of electrons
    4) an excess of atoms

35. Which of the following is needed for the heating part of most electric toasters?

    1) large current of electricity
    2) large wiring
    3) good conductor of electricity
    4) many atoms moving through wire

36. Which of the following does not depend upon heat made by electricity?

    1) electric motor
    2) electric fuse
    3) electric coffee pot
    4) electric iron

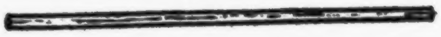
37. Which of the following is usually a good conductor of electricity?

    1) water 2) cotton 3) metal 4) wood

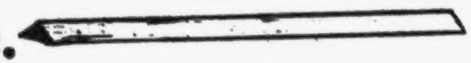
J-24

A.

B.



C.



D.

38. If the same amount of electricity flows through each of the wires above, which wire will be coldest (lowest temperature)?

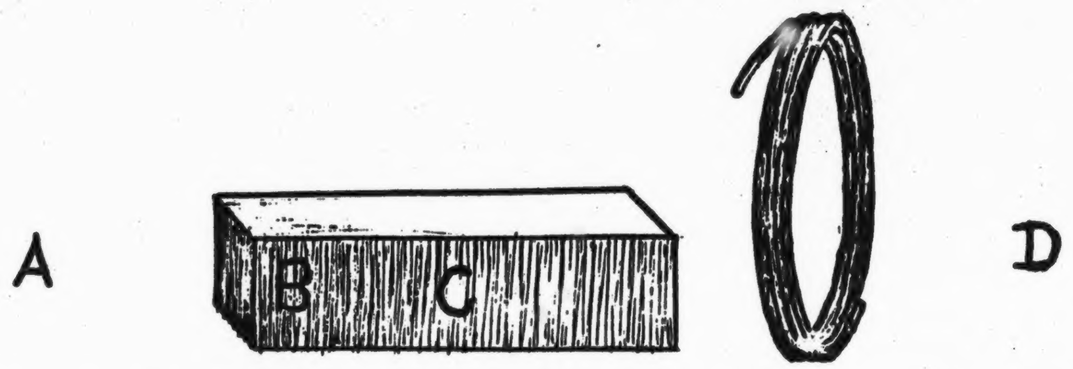
1) A  2) B  3) C  4) D

39. If the same amount of electricity flows through each of the wires above, which wire will be the hottest (highest temperature)?

1) A  2) B  3) C  4) D

40. If 4 wires are as large as those shown above, which wire would probably be used for a light bulb?

1) A  2) B  3) C  4) D



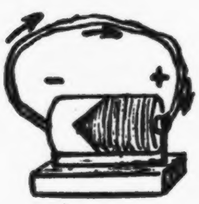
41. In the drawing above, a copper wire coil is moved over the bar magnet. Which of the following happens?

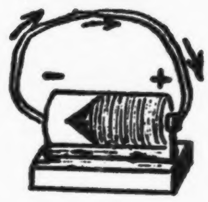
1) a magnetic field is made in the magnet
2) electric current flows in the wire
3) the magnet's N-pole becomes S-pole
4) the magnet attracts the wire

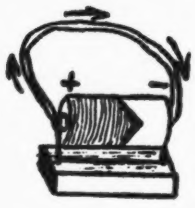
42. Look at the bar magnet above. At which place (A,B,C,D) is the magnetic field the strongest?

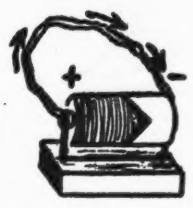
1) A 2) B 3) C 4) D

43. Four flashlight cells are shown below. Which one shows correctly the path of electricity?

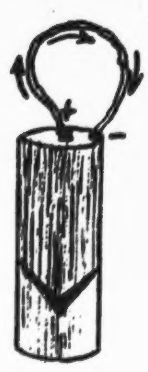
1


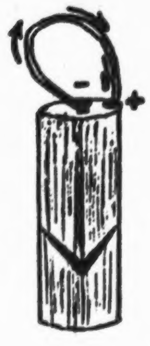
2


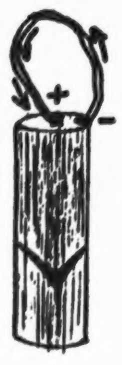
3


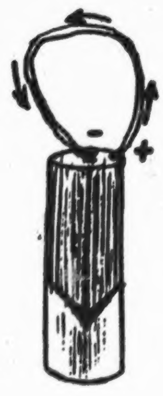
4


44. Below are 4 dry cell batteries. Which one correctly shows the flow of an electric current?

1)


2)


3)


4)


45. What is the purpose of an electric generator?

1) make A. C. electricity
2) make D. C. electricity
3) prevent A. C. electricity
4) make both A. C. and D. C. electricity

46. In which of the following is an electromagnet very important?

1) in toasters
2) in batteries
3) in motors
4) in electric lights

47. When we talk about electricity, what is the meaning of D. C. ?

1) electricity flows in one direction
2) electricity flows back and forth
3) electricity flows down circuit
4) electricity flows in two directions

48. When electricity flows through an insulated coil of wire, what else is needed to make a strong electromagnet?

1) any metal
2) iron rod
3) any conductor
4) any non-conductor

49. What happens to an electromagnet when its current of electricity is stopped?

1) the poles are reversed
2) its force increases
3) its force ends
4) its strength remains unchanged

50. When we talk about electricity, what is the meaning of A. C. ?

1) electricity flows in one direction
2) electricity flows in two directions
3) electricity flows across circuit
4) electricity flows back and forth

Table 217 PREFERRED ANSWERS TO QUESTIONS ON ELECTRICITY TEST

| Test Item | Preferred Answer | Test Item | Preferred Answer |
|---|---|---|---|
| 1 | 3 | 26 | 3 |
| 2 | 4 | 27 | 4 |
| 3 | 2 | 28 | 3 |
| 4 | 1 | 29 | 4 |
| 5 | 3 | 30 | 3 |
| 6 | 1 | 31 | 4 |
| 7 | 4 | 32 | 1 |
| 8 | 3 | 33 | 2 |
| 9 | 2 | 34 | 3 |
| 10 | 4 | 35 | 1 |
| 11 | 4 | 36 | 1 |
| 12 | 2 | 37 | 3 |
| 13 | 2 | 38 | 4 |
| 14 | 3 | 39 | 1 |
| 15 | 1 | 40 | 1 |
| 16 | 1 | 41 | 2 |
| 17 | 2 | 42 | 2 |
| 18 | 4 | 43 | 1 or 2 |
| 19 | 4 | 44 | 3 |
| 20 | 3 | 45 | 4 |
| 21 | 3 | 46 | 3 |
| 22 | 2 | 47 | 1 |
| 23 | 4 | 48 | 2 |
| 24 | 2 | 49 | 3 |
| 25 | 1 | 50 | 4 |

J-28

## INSTRUCTIONS FOR POST-UNIT TEST ON HEAT

In the following test you will be asked questions about heat. After each question there will be four answers. You are to choose the best answer and mark the number of that answer on your answer sheet. Do not make any marks on the booklet. Make all marks on the answer sheet.

You are not expected to know all of the answers to these questions about heat. Don't feel bad if you don't know some of the correct answers. The purpose of this test is to find out how much boys and girls in the elementary schools know about heat after they have studied it in school. DO NOT GUESS WILDLY. If you do not know the answer to a question, skip over that question and go on to the next one.

You will not know all of the words in the test. Your teacher will read the questions and possible answers with you. This is done to help you with some of the hard words. Wait until the questions and answers have been read. Then select the correct answer, if you know it. If you do not know the correct answer, you may darken the space under answer #5.

Let's look at this sample question:

1. Which of the following planets is farthest from the Sun?

1. Earth 2. Mars 3. Saturn 4. Pluto

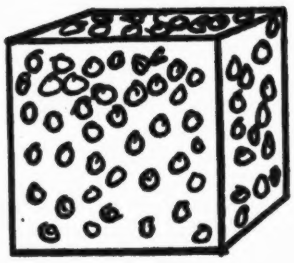
Which is the correct answer: Yes, ______________ is the right answer, and so you would darken the space on your answer sheet under __________________ .

If you wish to change an answer, erase the first mark carefully. Then make your new choice by darkening the space under the number of your new choice.

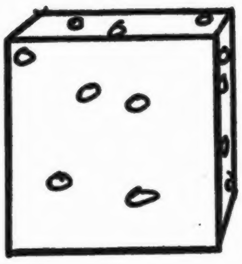
As soon as everyone is ready, we will begin. There are _________pages to this test.

Are there any questions?

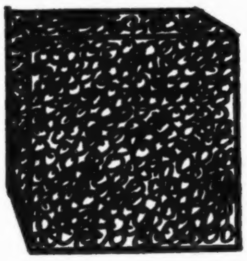
A



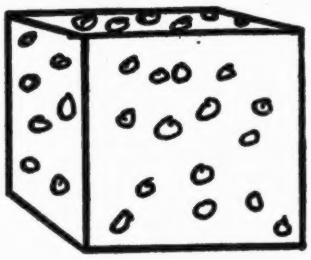
B



C



D



1. The pictures above show what molecules may look like. Which is the best picture of molecules in a gas?

   1. A 2. B 3. C 4. D

2. Which picture above shows how molecules may be in a solid?

   1. A 2. B 3. C 4. D

3. Which pictures above show how molecules might be in a liquid?

   1. A and B 2. B and C 3. A and C 4. A and D

4. Look at the pictures above. If all molecules are removed, what happens to the temperature inside the containers?

   1. There is no temperature
   2. Temperature doesn't change
   3. Temperature falls and then rises
   4. Temperature rises

5. Where does most heat energy come from?

   1. equator 2. ocean 3. sun 4. machines

6. Which of the following words best explain the meaning of heat energy?

   1. Light changed to heat
   2. Motion of molecules
   3. Explosion
   4. Friction

7. Which of the following will produce heat energy?

    1. Going down a slide
    2. Starting a car's motor
    3. A lighted lamp
    4. All of the above

8. Which of the following would have the highest temperature?

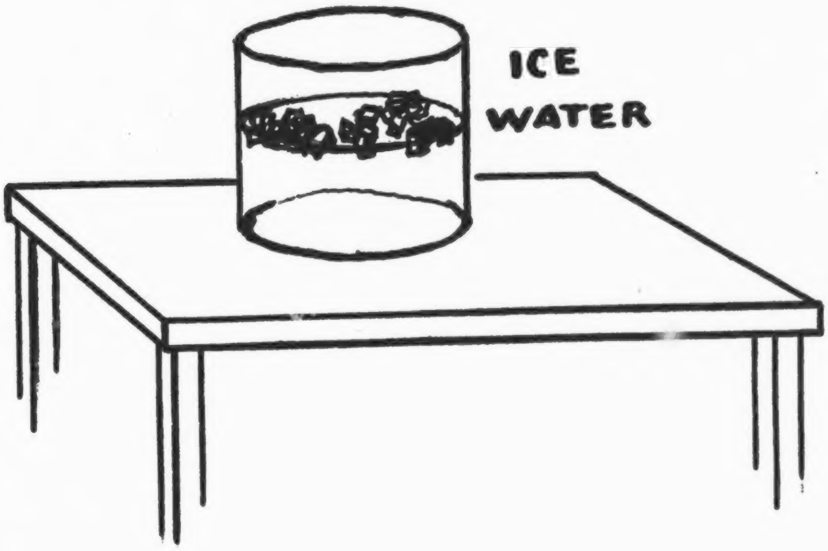
    1. Flaming match
    2. Atlantic Ocean
    3. Exploding volcano
    4. Sun's surface

9. Which of the following would have the most heat energy?

    1. Exploding volcano
    2. Jet airliner
    3. Atlantic Ocean
    4. Flaming match

10. Which of the following is the highest temperature?

    1. 90°C
    2. 110°F
    3. Boiling water
    4. All have same temperature



11. The picture above shows a jar of water with ice cubes. What is the temperature of the ice water?

    1. 100°F
    2. 0°C
    3. 32°C
    4. 0°F

12. If the jar in the picture above is heated, what happens first?

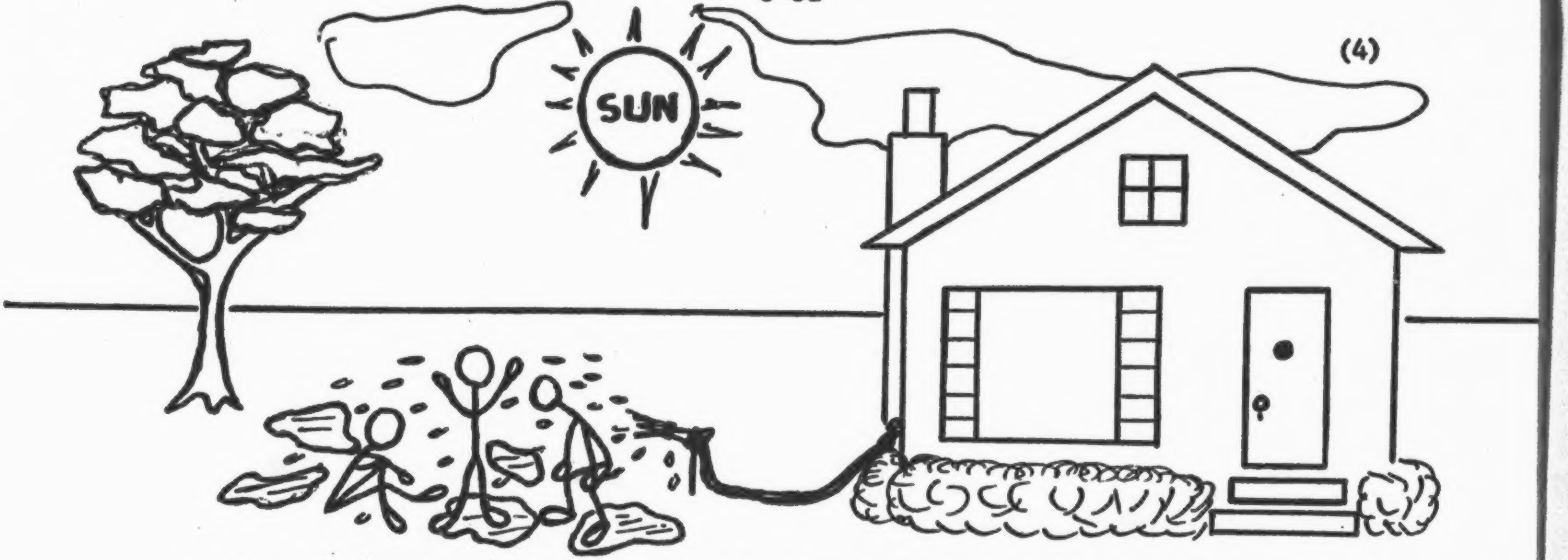
    1. Ice sinks
    2. Water boils
    3. Water changes to ice
    4. Ice melts

13. If the jar is heated, what happens to the molecules of ice water?

    1. They slow down
    2. They lose energy
    3. They move faster
    4. They melt

14. If all heat is taken away from the jar, what happens to the ice water?

    1. It changes to air
    2. Its temperature falls
    3. Its temperature rises
    4. It becomes a gas



In the figure above, the stick children are playing in the cold water from the hose.

15. What happens when the cold water hits the children?

    1. Water gains heat
    2. Children lose heat
    3. Children are cooled
    4. All of the above happen

16. What happens to the puddles of water in the sunlight?

    1. Puddles change to gas
    2. Puddles give heat to sun
    3. Puddles change to solid
    4. Puddles take gas from air

17. Which of the following helps to form clouds?

    1. Sunshine
    2. Water from the hose
    3. Puddles of water evaporate
    4. All of the above help

18. As the wet children run to the house, why do they feel cold?

    1. Because wind is cool
    2. Because water evaporates from bodies
    3. Because sun isn't very bright
    4. All of the above cause it

19. In the picture above, where is most of the radiant energy coming from?

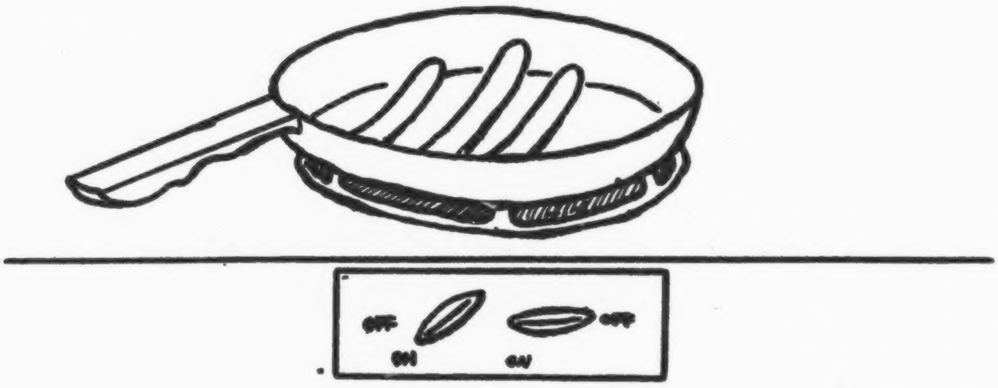
    1. sun 2. children 3. house 4. chimney

20. What happens to the radiant energy which earth receives from the sun?

    1. It changes its form
    2. It no longer exists
    3. Most heat is returned to sun
    4. The energy is all used up

21. Which of the following depends upon convection?

    1. Weather changes
    2. Wind
    3. House ventillation
    4. All of the above



22. In the picture above, hot dogs are cooking in the pan. How do you know that a gas is being formed?

    1. See gas forming
    2. Smell odor of hot dogs
    3. Hot dogs turn brown
    4. Hot dog gets bigger

23. In the picture above, how do you know that a liquid is being formed?

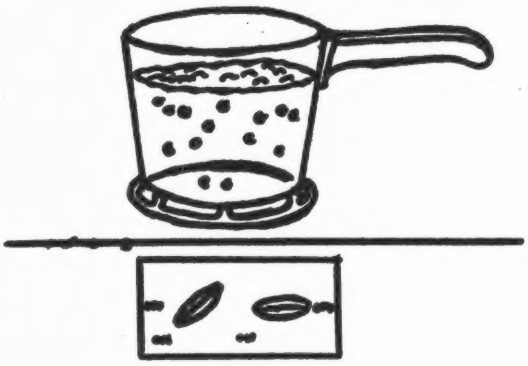
    1. See brown color of hot dogs
    2. Hot dog gets bigger
    3. See grease drip from hot dog
    4. Smell odor of hot dogs

24. Which of the following is the result of heat convection?

    1. Seeing hot dog turn brown
    2. Smelling hot dogs
    3. Watching hot dog get bigger
    4. Burning finger on stove

25. Heat energy moves by ____________________.

1. Radiation
2. Conduction
3. Convection
4. All of the above



26. In the picture above, the pan of water is being heated on the stove. What is happening to the pan?

1. It is not changed
2. It is contracting
3. It is expanding
4. All of the above happen to pan

27. To cook food quickly in the pan of water, the pan should be made of ____________________.

1. wood 2. metal 3. paper 4. asbestos

28. In the picture above, what happens to the air above the pan of water?

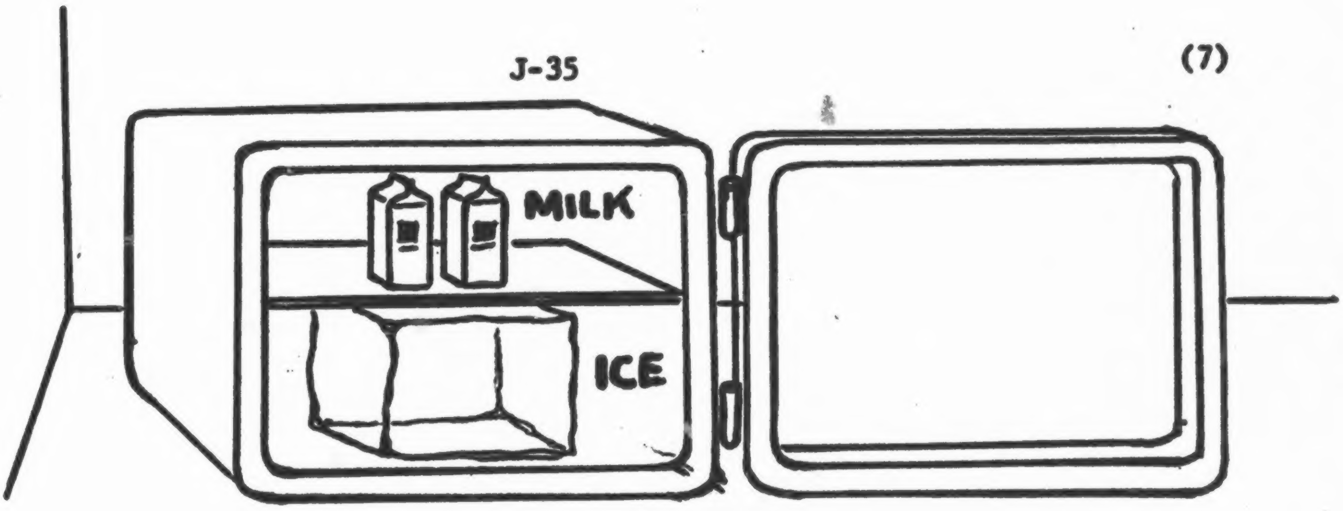
1. It is forced upward
2. It contracts
3. It is pulled down into the water
4. It changes to a liquid

29. In the picture above, which of the following would be most useful for the handle of the pan?

1. aluminum 2. wood 3. steel 4. copper

30. Which of the following are poor conductors of heat?

1. Paper and iron
2. Air and water
3. Steel and copper
4. All of the above are poor conductors



31. In the picture above, the door of the refrigerator has just been opened. In which direction does most of the heat travel?

    1. From milk to ice
    2. From ice to milk
    3. From room into refrigerator
    4. From refrigerator into the room

32. In the picture above, what happens to cold air in the refrigerator?

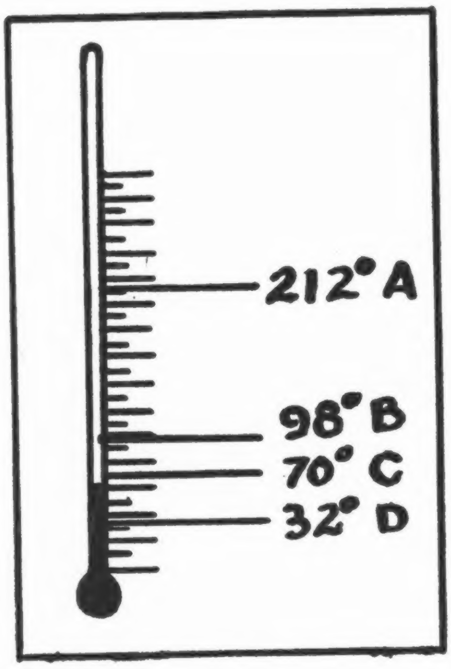
    1. It falls out onto the floor
    2. It stays inside refrigerator
    3. It rises to top of refrigerator
    4. It mixes equally with warm air

33. Which of the following would be a good insulator for the refrigerator?

    1. Glass
    2. Air
    3. Paper
    4. All of the above

34. If an insulator was used in the refrigerator, what is its purpose?

    1. Keep heat from entering refrigerator
    2. Keep cold from entering refrigerator
    3. Force heat into refrigerator
    4. Force heat out of the refrigerator



**FAHRENHEIT THERMOMETER**

35. In the thermometer shown above, which temperature would you expect to find for a glass of ice water?

1. A  2. B  3. C  4. D

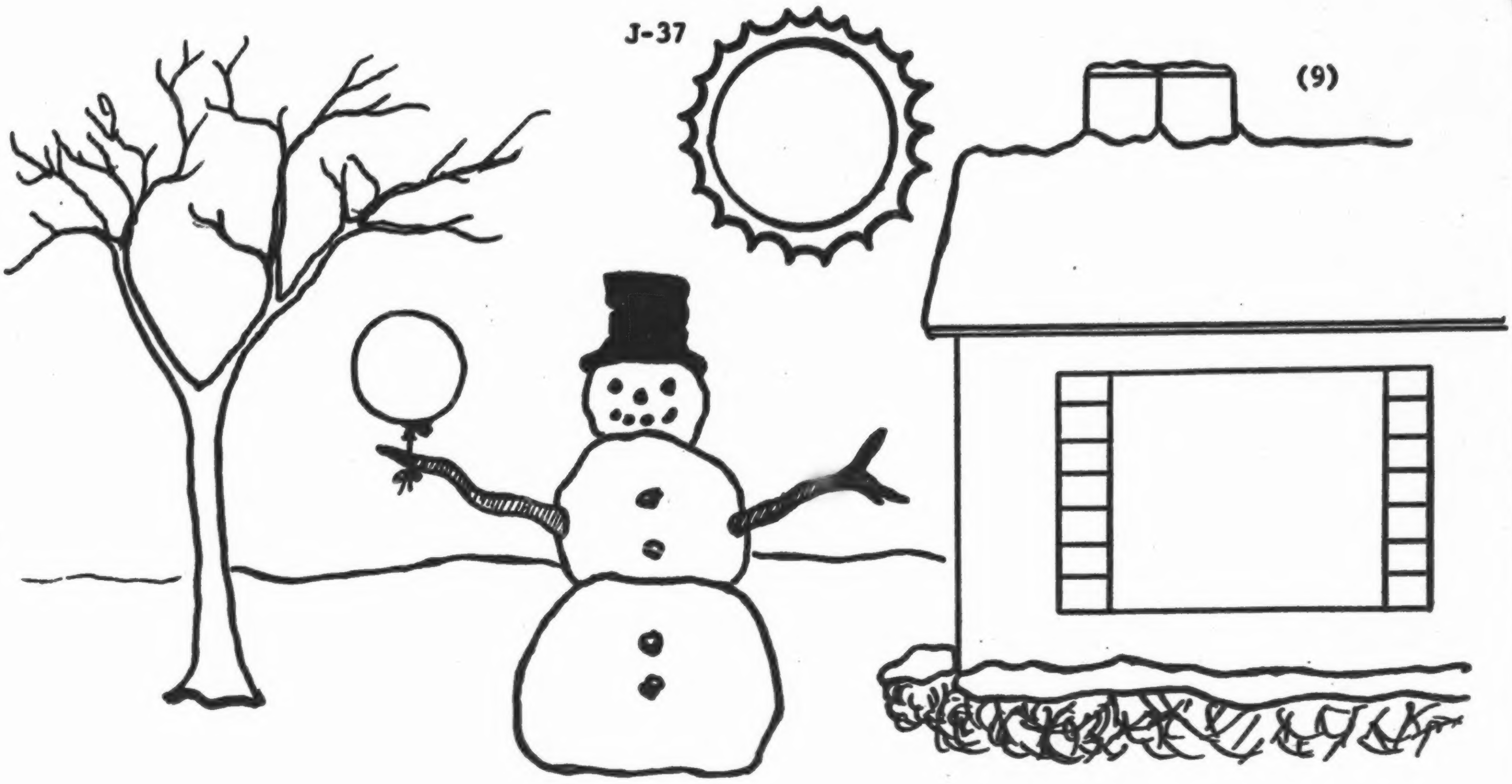
36. In the thermometer shown above, which temperature would you expect to find for a healthy boy or girl?

1. A  2. B  3. C  4. D

37. In the thermometer shown above, which temperature would you expect to find for boiling water?

1. A  2. B  3. C  4. D

J-37



38. In the picture above, a child has blown up a balloon in the warm house and carried it outside to place on the snowman. What will happen to the balloon?

    1. It gets bigger
    2. It changes color
    3. It becomes smaller
    4. It remains the same

39. In the picture above, what happens to the air inside the snowman's balloon?

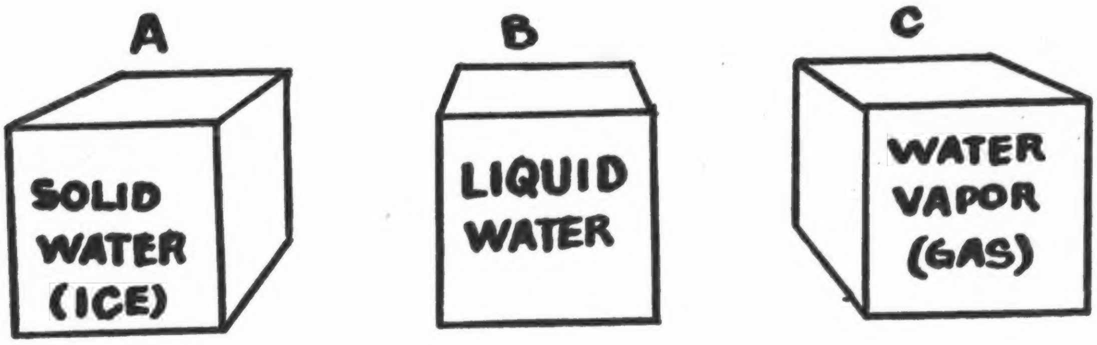
    1. Molecules move faster
    2. Molecules gain heat energy
    3. Molecules get bigger
    4. Molecules lose heat energy

40. In the picture above, what causes the snowman to melt?

    1. Heat from sun's rays
    2. Sun sends warm air
    3. Heat conducted from house
    4. Convection from the sun

41. In the picture above, which of the following will have the highest temperature?

    1. Water from melting snow
    2. Small ball of snow
    3. Air around snowman
    4. Snowman's hat



42. In the pictures above, the containers are the same size. Compare the weights of the three containers.

    1. A weighs most
    2. B weighs most
    3. C weighs most
    4. All weigh the same

43. In the pictures above, compare the number of molecules in each container.

    1. A has most molecules
    2. B has most molecules
    3. C has most molecules
    4. Same number of molecules in each container

44. In the pictures above, compare the energy of a single molecule in each container.

    1. Molecule in A has most energy
    2. Molecule in B has most energy
    3. Molecule in C has most energy
    4. All molecules have same amount of energy

45. Which of the following is the best example of heat conduction?

    1. Electric light bulb
    2. Smoke rising from chimney
    3. Burn finger touching match
    4. Sun sending heat to earth

46. Which of the following is the best example of convection?

    1. Mercury rising in thermometer
    2. Sun sending heat to earth
    3. Burn finger touching match
    4. Heating inside of home

47. Which of the following is a good example of radiation?

    1. Sun sending heat to earth
    2. Burn finger touching match
    3. Smoke rising from chimney
    4. All of the above

48. What causes ice to float on water?

    1. It adds heat to the water
    2. Its molecules are lighter than water
    3. It expands upon freezing
    4. It weighs more than water

49. Which of the following materials can give off radiant energy?

    1. People
    2. Light bulbs
    3. Cars
    4. All of these

50. What causes the red material in thermometers to go up?

    1. Adding heat
    2. It contracts
    3. Removing heat
    4. It's a gas

J-40

Table 218 PREFERRED ANSWERS TO QUESTIONS ON HEAT TEST

| Test Item | Preferred Answer | Test Item | Preferred Answer |
|---|---|---|---|
| 1 | 2 | 26 | 3 |
| 2 | 3 | 27 | 2 |
| 3 | 4 | 28 | 1 |
| 4 | 1 | 29 | 2 |
| 5 | 3 | 30 | 2 |
| 6 | 2 | 31 | 3 |
| 7 | 4 | 32 | 1 |
| 8 | 4 | 33 | 4 |
| 9 | 3 | 34 | 1 |
| 10 | 3 | 35 | 4 |
| 11 | 2 | 36 | 2 |
| 12 | 4 | 37 | 1 |
| 13 | 3 | 38 | 3 |
| 14 | 2 | 39 | 4 |
| 15 | 4 | 40 | 1 |
| 16 | 1 | 41 | 4 |
| 17 | 4 | 42 | 2 |
| 18 | 2 | 43 | 2 |
| 19 | 1 | 44 | 3 |
| 20 | 1 | 45 | 3 |
| 21 | 4 | 46 | 4 |
| 22 | 2 | 47 | 1 |
| 23 | 3 | 48 | 3 |
| 24 | 2 | 49 | 4 |
| 25 | 4 | 50 | 1 |

## Appendix K-1
## SAMPLE OF QUESTIONNAIRE MAILED TO TEACHERS AFTER EACH UNIT WAS TAUGHT

1. Teacher's Name ______________________________.

2. On what date did instruction begin? ________________, 1966.

3. On what date did instruction end? ________________, 1966.

4. Please list the names of any pupils who missed more than three days of your instruction. ______________________________
______________________________.

5. How many days per week (approximately) was the unit taught? ________days/week.

6. How much time (approximately) was used for each day of instruction? ________________min/day.

7. Questions regarding plan of instruction:

   a) Which teaching procedure did you tend to follow?

      Mostly Lecture ________________

      Mostly Teacher Demonstration ________________

      Mostly Teacher & Pupil Demonstration ________________

      Mostly Pupil Activities ________________

      Other ________________

   b) What were strong points of unit plan? ________________
   ______________________________.

   c) What were weak points of unit plan? ________________
   ______________________________.

   d) Did children make projects outside of school?__________.

8. Did any unusual events occur which may have affected pupils' favorably or unfavorably?______________________________
______________________________.

K-2

9. To your knowledge, were there any pupils in your class who had physical handicaps or emotional problems which seriously interferred with their participation in the testing or regular class activities? If you know of such pupils, please write the names here. ________

END

4/24/68